PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

VOL. XLII—No. 1

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(INSTITUTED 1852)

VOL. XLII—No. 1

JANUARY, 1916

Edited by the Secretary, under the direction of the Committee on Publications.

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NEW YORK 1916

American Society of Civil Engineers

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ON VALUATION OF PUBLIC UTILITIES: Frederic P. Stearns, Charles S. Churchill, Leonard Metcalf, William G. Raymond, Henry E. Riggs, Jonathan P. Snow, William J. Wilgus.

TO INVESTIGATE CONDITIONS OF EMPLOYMENT OF, AND COMPENSATION OF, CIVIL ENGINEERS: Nelson P. Lewis, S. L. F. Deyo, Dugald C. Jackson, William V. Judson, George W. Tillson, C. F. Loweth, John A. Bensel.

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ON FLOODS AND FLOOD PREVENTION: C. McD. Townsend, John A. Bensel, T. G. Dabney, C. E. Grunsky, Morris Knowles, J. B. Lippincott, Daniel W. Mead, John A. Ockerson, Arthur T. Safford, Charles Saville, F. L. Sellew.

TO REPORT ON STRESSES IN RAILROAD TRACK: A. N. Talbot, A. S. Baldwin, J. B. Berry, G. H. Bremner, John Brunner, W. J. Burton, Charles S. Churchill, W. C. Cushing, Robert W. Hunt, George W. Kittredge, Paul M. LaBach, C. G. E. Larsson, William McNab, G. J. Ray, Albert F. Reichmann, F. E. Turneaure, J. E. Willoughby.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

TELEPHONE NUMBER........................1446 Circle.
CABLE ADDRESS......................"Ceas, New York."

Vol. XLII. JANUARY, 1916. No. 1.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PROCEEDINGS

SOCIETY AFFAIRS

CONTENTS

MINUTES OF MEETINGS

OF THE SOCIETY

December 15th, 1915.—The meeting was called to order at 8.30 P. M.; Director George W. Fuller in the chair; Chas. Warren Hunt, Secretary; and present, also, 90 members and 12 guests.

A paper by Benjamin F. Groat, M. Am. Soc. C. E., entitled "Chemi-Hydrometry and Its Application to the Precise Testing of Hydro-Electric Generators", was presented by the author and illustrated with lantern slides. The paper was discussed by Messrs. George W. Fuller, Thomas H. Wiggin, and the author.

(After the meeting, Mr. Groat demonstrated the titration of samples of salt solution with the chemicals used in making chemi-hydrometric tests.)

The Secretary announced the following deaths:

Charles Abbott Locke, of Nashville, Tenn., elected Member, October 3d, 1888; died November 12th, 1915.

Irvine Watson, of Salem, Ore., elected Associate Member, June 3d, 1903; Member, March 3d, 1908; died November 24th, 1915.

Adjourned.

January 5th, 1916.—The meeting was called to order at 8:30 P. M.; J. Waldo Smith, M. Am. Soc. C. E., in the chair; Chas. Warren Hunt, Secretary; and present also 201 members and 41 guests.

The minutes of the meetings of November 17th and December 1st, 1915, were approved as printed in *Proceedings* for December, 1915.

A paper by William P. Creager, M. Am. Soc. C. E., entitled "The Economical Top Width of Non-Overflow Dams" was presented by the author, and discussed by Orrin L. Brodie, M. Am. Soc. C. E.

Ernest F. Robinson, Assoc. M. Am. Soc. C. E., Captain, 22d Reg., Engrs., N. G. N. Y., addressed the meeting on the work of the Corps of Engineers of the National Guard of the State of New York, illustrating his remarks with lantern slides, models, and apparatus. Messrs. E. W. V. C. Lucas, G. D. Snyder, and F. W. Skinner also spoke on the subject.

The Secretary announced the following deaths:

William Weeden Cole, of New York City, elected Member, October 7th, 1903; died December 20th, 1915.

Grenville Mellen Dodge, of Council Bluffs, Iowa, elected Honorary Member, March 2d, 1915; died January 3d, 1916.

Emory Alexander Ellsworth, of Holyoke, Mass., elected Member, June 1st, 1904; died December 8th, 1915.

Thomas Franklin Richardson, of Rutherford, N. J., elected Member, November 4th, 1885; died December 26th, 1915.

Francis Winthrop Scarborough, of Richmond, Va., elected Junior, September 3d, 1890; Associate Member, March 6th, 1895; Member, February 2d, 1904; died December 24th, 1915.

Edward Dana Wickes, of Lindsay, Cal., elected Associate Member, December 3d, 1902; Member, October 2d, 1906; died June 11th, 1915.

Adjourned.

ANNOUNCEMENTS

The House of the Society is open from 9 A. M. to 10 P. M., every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

FUTURE MEETINGS

February 2d, 1916.—8.30 P. M.—This will be a regular business meeting. Two papers will be presented for discussion, as follows: "The Failure and Righting of a Million-Bushel Grain Elevator", by Alexander Allaire, M. Am. Soc. C. E.; and "Cohesion in Earth: The Need for Comprehensive Experimentation to Determine the Coefficients of Cohesion", by William Cain, M. Am. Soc. C. E.

These papers were printed in *Proceedings* for December, 1915.

February 16th, 1916.—8.30 P. M.—At this meeting, a paper by A. B. Lueder, M. Am. Soc. C. E., and W. J. R. Wilson, Esq., entitled "Secure Subway Supports," will be presented for discussion.

This paper is printed in this number of *Proceedings*.

March 1st, 1916.—8.30 P. M.—A regular business meeting will be held, and two papers will be presented for discussion, as follows: "A Study of the Behavior of Rapid Sand Filters Subjected to the High-Velocity Method of Washing", by Joseph W. Ellms, M. Am. Soc. C. E., and John S. Gettrust, Esq.; and "The Effects of Straining Structural Steel and Wrought Iron," by Henry S. Prichard, M. Am. Soc. C. E.

These papers are printed in this number of *Proceedings*.

SEARCHES IN THE LIBRARY

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

In making a search it sometimes happens that references are found which are not readily accessible to the person for whom the search is made. In that case the material may be reproduced by photography, and this can be done for members at the cost of the work to the Society, which is small. This method is particularly useful when there are drawings or figures in the text, which would be very expensive to reproduce by hand.

PAPERS AND DISCUSSIONS

Members and others who take part in the oral discussions of the papers presented are urged to revise their remarks promptly. Written communications from those who cannot attend the meetings should be sent in at the earliest possible date after the issue of a paper in *Proceedings.*

All papers accepted by the Publication Committee are classified by the Committee with respect to their availability for discussion at meetings.

Papers which, from their general nature, appear to be of a character suitable for oral discussion, will be published as heretofore in *Proceedings*, and set down for presentation to a future meeting of the Society, and on these, oral discussions, as well as written communications, will be solicited.

All papers which do not come under this heading, that is to say, those which from their mathematical or technical nature, in the opinion of the Committee, are not adapted to oral discussion, will not be scheduled for presentation to any meeting. Such papers will be published in *Proceedings* in the same manner as those which are to be presented at meetings, but written discussions only will be requested for subsequent publication in *Proceedings* and with the paper in the volumes of *Transactions.*

The Board of Direction has adopted rules for the preparation and presentation of papers, which will be found on page 429 of the August, 1913, *Proceedings.*

LOCAL ASSOCIATIONS OF MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

San Francisco Association

The San Francisco Association of Members of the American Society of Civil Engineers holds regular bi-monthly meetings, with banquet, and weekly informal luncheons. The former are held at 6 P. M., at the Palace Hotel, on the third Friday of February, April, June, August, October, and December, the last being the Annual Meeting of the Association.

Informal luncheons are held at 12.15 P. M., every Wednesday, and the place of meeting may be ascertained by communicating with the Secretary of the Association, E. T. Thurston, 713 Mechanics' Institute, 57 Post Street.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in San Francisco, and any such member will be gladly welcomed as a guest.

(Abstract of Minutes of Meetings)

October 15th, 1915.—The meeting was called to order at the Palace Hotel; Vice-President Haehl in the chair; E. T. Thurston, Secretary; and present, also, 64 members and guests.

Mr. C. E. Grunsky, Chairman of the Committee of Arrangements for the Annual Convention, presented the Report of that Committee, and on motion, duly seconded, the Board of Directors was authorized to incur an additional expense of $216.80.

Mr. C. H. Snyder reported that the Board of Directors had considered the question of establishing a class in public speaking and had decided to send out a postal inquiry to the members of the Association relative to the matter.

Messrs. Shaw and Barrett, of the Public Service Commission of Illinois, and of the United States Steel Products Company, respectively, addressed the meeting briefly.

Messrs. J. H. Dockweiler, J. B. Pope, and W. C. Hammatt, were appointed by the Chair as the Entertainment Committee for the next meeting.

Mr. H. C. Vensano addressed the meeting on the Spaulding-Drum Power Development of the Pacific Gas and Electric Corporation, illustrating his remarks with stereopticon views. The subject was discussed by Messrs. Barrett, Duryea, Fowler, Grunsky, Huber, Hyde, Marx, Nishkian, O'Shaughnessy, Rhodin, Snyder, and Wing.

Adjourned.

December 17th, 1915.—The Eleventh Annual Meeting was called to order; Vice-President M. C. Couchot in the chair; E. T. Thurston, Secretary; and present, also, 49 members and guests.

On motion, duly seconded, a communication from Mr. Edwin Duryea, Jr., relative to changing the meeting night to one more convenient than Friday, was referred to the Board of Directors to provide a letter ballot.

A communication from Mr. Jerome Newman was read, suggesting that the views of the members of the Association be ascertained relative to the extent to which it is justifiable for one engineer to use the plans and specifications of another without permission of or credit to the latter. After a brief discussion by Messrs. Newman, Marx, Brunnier, Rhodin, and Duryea, on motion, duly seconded, it was ordered that a committee of five be appointed to define principles of ethics in engineering practice and report at a subsequent meeting.

The Annual Reports of the Secretary and Treasurer were read.

The Secretary called attention to the prize competition open to Junior members, through the generosity of Mr. Henry A. Schulze, until May 15th, 1916, and the older members were urged to use their influence to secure the submission of suitable papers from Junior members.

Messrs. Dillman, Meredith, and O'Shaughnessy, were appointed as the Entertainment Committee for the February meeting.

In response to an inquiry from Mr. E. F. Kriegsman relative to the result of the postal card inquiry in regard to the formation of a class in public speaking under the auspices of the Association, the Secretary reported that out of 175 inquiries sent out, 70 replies had been received, 19 of which were opposed to the plan, 25 approved the plan, but would not join a class, and 26 approved and would join a class under suitable conditions. In reply to a request for definite support from the Association, Vice-President Couchot reported that the Board of Directors considered it outside the scope of the Association to assume responsibility, but that any group of members could proceed with the matter and would receive all the assistance the Association could afford them. After discussion by Messrs. Kriegsman, Haehl, and Marx, a motion that the Association appoint a committee to organize a class was lost.

The following officers were elected: President, H. L. Haehl, and Vice-President, Jerome Newman.

A paper by Mr. H. L. Haehl, entitled "Water-Right Litigation in the Santa Clara Valley", was presented by the author, who illustrated his remarks with stereopticon views.

Adjourned.

Colorado Association

The meetings of the Colorado Association of Members of the American Society of Civil Engineers (Denver, Colo.) are held on the second Saturday of each month, except July and August. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary, L. R. Hinman, 1400 West Colfax Ave., Denver, Colo. The meetings are usually preceded by an informal dinner. Members of the American Society of Civil Engineers will be welcomed at these meetings.

Weekly luncheons are held on Wednesdays, at 12.30 P. M., at Clarke's Restaurant, 1632 Champa Street.

Visiting members are urged to attend the meetings and luncheons.

Atlanta Association

The Atlanta Association of Members of the American Society of Civil Engineers was organized on March 14th, 1912. The Association holds its meetings at the University Club, Atlanta, Ga.

At the meeting of the Association on January 9th, 1915, the following officers were elected for the ensuing year: President, Park A. Dallis; First Vice-President, B. M. Hall; Second Vice-President, P. H. Norcross; Secretary-Treasurer, T. B. Branch.

Baltimore Association

On May 6th, 1914, the Baltimore Association of Members of the American Society of Civil Engineers was organized, a Constitution adopted, and the following officers were elected: J. E. Greiner, President; Francis Lee Stuart, First Vice-President; L. H. Beach, Second Vice-President; Harry D. Williar, Jr., Secretary-Treasurer; and Messrs. H. D. Bush, B. T. Fendall, B. P. Harrison, Calvin W. Hendrick, Oscar F. Lackey, M. A. Long, and A. A. Thompson, Directors.

At its meeting of September 2d, 1914, the Board of Direction considered and approved the proposed Constitution of the Baltimore Association of Members of the American Society of Civil Engineers.

Cleveland Association

The proposed Constitution of the Cleveland Association of Members of the American Society of Civil Engineers was considered and approved by the Board of Direction of the Society on January 6th, 1915.

At the meeting of the Association on December 18th, 1915, the following officers were elected for the ensuing year: President, Robert Hoffman; Vice-President, Wilbur J. Watson; and Secretary-Treasurer, George H. Tinker.

Louisiana Association

At the meeting of the Louisiana Association of Members of the American Society of Civil Engineers (New Orleans, La.), on April 14th, 1915, the following officers were elected for the ensuing year: J. F. Coleman, President; W. B. Gregory and A. M. Shaw, Vice-Presidents; Ole K. Olsen, Treasurer; and E. H. Coleman, Secretary.

Northwestern Association

The proposed Constitution of the Northwestern Association of Members of the American Society of Civil Engineers (St. Paul and Minneapolis, Minn.) was considered and approved by the Board of Direction of the Society on November 4th, 1914. F. W. Cappelen is President and R. D. Thomas, Secretary.

Philadelphia Association

The meetings of the Philadelphia Association of Members of the American Society of Civil Engineers are held at the Engineers' Club of Philadelphia, 1317 Spruce Street.

The officers of the Association are as follows: President, Edward B. Temple; Vice-Presidents, Edgar Marburg and John Sterling Deans; Directors, J. W. Ledoux, H. S. Smith, Henry H. Quimby, and George A. Zinn; Past-Presidents, George S. Webster and Richard L. Humphrey; Treasurer, S. M. Swaab; and Secretary, W. L. Stevenson.

Portland, Ore., Association

At the Annual Meeting of the Association on September 28th, 1915, the following officers were elected for the ensuing year: President, J. P. Newell; First Vice-President, John T. Whistler; Second Vice-President, E. B. Thomson; Treasurer, Russell Chase; and Secretary, J. A. Currey.

St. Louis Association

The proposed Constitution of the St. Louis Association of Members of the American Society of Civil Engineers was considered and approved by the Board of Direction of the Society on October 7th, 1914.

The following officers have been elected: President, J. A. Ockerson; First Vice-President, Edward E. Wall; Second Vice-President, F. J. Jonah; Secretary-Treasurer, Gurdon G. Black. The meetings of the Association are held at the Engineers' Club Auditorium.

San Diego Association

The San Diego Association of Members of the American Society of Civil Engineers was organized on February 5th, 1915, and officers have been elected, as follows: President, George Butler; Vice-President, Willis J. Dean; and Secretary-Treasurer, J. R. Comly.

At its meeting of September 20th, 1915, the Board of Direction considered and approved the proposed Constitution of the San Diego Association of Members of the American Society of Civil Engineers.

Seattle Association

The Seattle Association of Members of the American Society of Civil Engineers was organized on June 30th, 1913. At its meeting of January 25th, 1915, the following officers were elected for the ensuing year: President, R. H. Ober; Vice-President, A. S. Downey; and Secretary-Treasurer, Carl H. Reeves.

(Abstract of Minutes of Meetings)

November 29th, 1915.—The meeting was called to order at 12.15 P. M., at the College Club; President R. H. Ober in the chair; Carl H. Reeves, Secretary; and present, also, 19 members and guests.

The minutes of the meeting of October 25th, 1915, were read and approved.

In reply to an invitation from the Washington State Reclamation Conference, the President was directed to appoint a delegate from the Association to the Western States Convention to be held in San Francisco on December 2d-3d, 1915.

Mr. Robert Howes, Chairman of the Conference Committee, reported on the final form of The Articles of Association for the Affiliated Engineering Societies of Seattle. On motion, duly seconded, the changes were approved, and the previously appointed representatives, Messrs. Howes and Hall, were empowered to act for the Association.

Mr. S. H. Hedges addressed the meeting briefly on the Re-Districting of the Membership of the Society, giving a general outline of the new Districts.

Adjourned.

December 27th, 1915.—The meeting was called to order at 12.15 P. M., at the College Club; President R. H. Ober in the chair; Carl H. Reeves, Secretary; and present also 22 members and guests.

The minutes of the meeting of November 29th, 1915, were read and approved.

The resignation of Mr. E. B. Crane as a member of the Association was accepted.

By unanimous vote, Mr. F. W. D. Holbrook was made an Honorary Member of the Association, and exempted from further payment of dues.

A copy of a letter sent to the *Oregon Building Record* by the County Clerk of Marion County, *in re* a bridge design competition for the Inter-County Bridge at Salem, Ore., was read, and the Secretary was requested to ascertain from the Portland, Ore., Association what, if any, action had been taken in the matter by that Association.

On motion, duly seconded, the President was directed to appoint a committee of five to arrange for the Annual Meeting of the Association to be held on January 31st, 1916. The Committee was appointed as follows: A. S. Downey, Chairman, Joseph Jacobs, A. H. Fuller, Bertram D. Dean, and Charles Albertson.

Brief addresses were made by Messrs. K. B. Kumpe and J. I. Horrocks.

Adjourned.

Southern California Association

The Southern California Association of Members of the American Society of Civil Engineers (Los Angeles, Cal.) holds regular bimonthly meetings, with banquet, on the second Wednesday of February, April, June, August, October, and December, the last being the Annual Meeting of the Association.

Informal luncheons are held at 12.15 P. M. every Wednesday, and the place of meeting may be ascertained from the Secretary of the Association, W. K. Barnard, 701 Central Building, Los Angeles, Cal.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in Los Angeles, and any such member will be gladly welcomed as a guest at any of the meetings or luncheons.

Spokane Association

The proposed Constitution of the Spokane Association of Members of the American Society of Civil Engineers was considered and approved by the Board of Direction of the Society on March 4th, 1914. Ulysses B. Hough is President.

Texas Association

The proposed Constitution of the Texas Association of Members of the American Society of Civil Engineers was considered and approved by the Board of Direction of the Society on December 31st, 1913. The headquarters of the Association is Dallas, Tex. John B. Hawley is President.

MINUTES OF MEETINGS OF SPECIAL COMMITTEES TO REPORT UPON ENGINEERING SUBJECTS

Special Committee on Steel Columns and Struts

November 19th, 1915.—The meeting was held at the Society House. Present, James H. Edwards, Rudolph P. Miller, George H. Pegram, Lewis D. Rights (Secretary), and George F. Swain.

The Secretary announced the appointment of Mr. Pegram as Chairman of the Committee, and his acceptance. Mr. Pegram took the chair, and the minutes of the meeting of June 23d, 1915, were approved.

Mr. Edwards reported on the progress of the material for the new column tests. Mr. Swain reported concerning a conference with Government authorities in regard to some former test programmes, and Mr. Worcester submitted by letter a report on proposed Factor of Safety. These reports were received and the committees continued.

The Progress Report of the Committee was considered, and, after correction, on motion by Mr. Swain, it was ordered sent to the Secretary of the Society for publication and presentation to the Annual Meeting. A typewritten copy was also ordered to be sent to each member of the Committee.

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms, and at all meetings:

American Institute of Electrical Engineers, 33 West Thirty-ninth Street, New York City.

American Institute of Mining Engineers, 29 West Thirty-ninth Street, New York City.

American Society of Mechanical Engineers, 29 West Thirty-ninth Street, New York City.

Architekten-Verein zu Berlin, Wilhelmstrasse 92, Berlin W. 66, Germany.

Associação dos Engenheiros Civis Portuguezes, Lisbon, Portugal.

Australasian Institute of Mining Engineers, Melbourne, Victoria, Australia.

Boston Society of Civil Engineers, 715 Tremont Temple, Boston, Mass.

Brooklyn Engineers' Club, 117 Remsen Street, Brooklyn, N. Y.

Canadian Society of Civil Engineers, 176 Mansfield Street, Montreal, Que., Canada.

Civil Engineers' Society of St. Paul, St. Paul, Minn.

Cleveland Engineering Society, Chamber of Commerce Building, Cleveland, Ohio.

Cleveland Institute of Engineers, Middlesbrough, England.

Dansk Ingeniorforening, Amaliegade 38, Copenhagen, Denmark.

Detroit Engineering Society, 46 Grand River Avenue, West, Detroit, Mich.

Engineers and Architects Club of Louisville, 1412 Starks Building, Louisville, Ky.

Engineers' Club of Baltimore, 6 West Eager Street, Baltimore, Md.

Engineers' Club of Kansas City, E. B. Murray, Secretary, 920 Walnut Street, Kansas City, Mo.

Engineers' Club of Minneapolis, 17 South Sixth Street, Minneapolis, Minn.

Engineers' Club of Philadelphia, 1317 Spruce Street, Philadelphia, Pa.

Engineers' Club of St. Louis, 3817 Olive Street, St. Louis, Mo.

Engineers' Club of Toronto, 96 King Street, West, Toronto, Ont., Canada.

Engineers' Club of Trenton, Trent Theatre Building, 12 North Warren Street, Trenton, N. J.

Engineers' Society of Northeastern Pennsylvania, 415 Washington Avenue, Scranton, Pa.

Engineers' Society of Pennsylvania, 31 South Front Street, Harrisburg, Pa.

Engineers' Society of Western Pennsylvania, 2511 Oliver Building, Pittsburgh, Pa.

Institute of Marine Engineers, The Minories, Tower Hill, London, E., England.

Institution of Engineers of the River Plate, Calle 25 de Mayo 195, Buenos Aires, Argentine Republic.

Institution of Naval Architects, 5 Adelphi Terrace, London, W. C., England.

Junior Institution of Engineers, 39 Victoria Street, Westminster, S. W., London, England.

Koninklijk Instituut van Ingenieurs, The Hague, The Netherlands.

Louisiana Engineering Society, State Museum Building, Chartres and St. Ann Streets, New Orleans, La.

Memphis Engineers' Club, Memphis, Tenn.

Midland Institute of Mining, Civil and Mechanical Engineers, Sheffield, England.

Montana Society of Engineers, Butte, Mont.

North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne, England.

Oesterreichischer Ingenieur= und Architekten=Verein, Eschenbachgasse 9, Vienna, Austria.

Oregon Society of Civil Engineers, Portland, Ore.

Pacific Northwest Society of Engineers, 312 Central Building, Seattle, Wash.

Rochester Engineering Society, Rochester, N. Y.

Sachsischer Ingenieur= und Architekten=Verein, Dresden, Germany.

Sociedad Colombiana de Ingenieros, Bogota, Colombia.

Sociedad de Ingenieros del Peru, Lima, Peru.

Societe des Ingenieurs Civils de France, 19 rue Blanche, Paris, France.

Society of Engineers, 17 Victoria Street, Westminster, S. W., London, England.

Svenska Teknologforeningen, Brunkebergstorg 18, Stockholm, Sweden.

Tekniske Forening, Vestre Boulevard 18–1, Copenhagen, Denmark.

Western Society of Engineers, 1737 Monadnock Block, Chicago, Ill.

ANNUAL REPORT OF THE BOARD OF DIRECTION FOR THE YEAR ENDING DECEMBER 31st, 1915.

In compliance with the Constitution, the Board of Direction presents its report for the year ending December 31st, 1915.

MEMBERSHIP

The changes in membership are shown in the following table:

	Jan. 1st, 1915.			Jan. 1st, 1916.			Losses.				Additions.		Totals.		
	Resident.	Non-Resident.	Total.	Resident.	Non-Resident.	Total.	Transfer.	Resignation.	Dropped.	Death.	Transfer.	Election.	Loss.	Gain.	Increase.
Honorary Members.	.....	6	6	.....	6	6	....	..	..	1	.....	1	1	1	....
Corresponding "	.....	1	1	.....	1	1	....	..	..	..	.....	.....	....	....	....
Members	658	2 744	3 402	668	2 763	3 431	....	16	21	56	†69	*53	93	122	29
Associate Members	569	2 679	3 248	607	2 880	3 487	67	32	27	12	‡90	287	138	377	239
Associates	69	97	166	68	99	167	3	1	1	2	§2	6	7	8	1
Juniors	160	680	840	147	656	803	91	17	40	3	.....	114	151	114	‖37
Fellows	5	10	15	6	8	14	....	..	..	1	.....	.....	1	....	‖1
Totals	1 461	6 217	7 678	1 496	6 413	7 909	161	66	89	75	161	461	391	622	231

*2 Reinstatements.
†67 Associate Members, 2 Associates.
‡1 Associate, 89 Juniors.
§2 Juniors.
‖ Decrease.

It will be noted that the net increase in membership for the year was 231.

This is a much smaller increase in membership than the Society has had in many years, and is undoubtedly due to general financial conditions. Although the total additions to the membership were 461, the losses by resignation and by failure to pay dues, most of which can be traced to the same cause, are much larger this year than is usual. The losses by death have also been very heavy.

The number of applications received during 1915 was 844: 591 for admission and 253 for transfer.

The losses by death during the year number 75, and are as follows:

Honorary Members (1): Thomas Coltrin Keefer.

Members (56): Edward Harding Barnes, Axel Samuel Frederick Berquist, Austin Lord Bowman, Dexter Brackett, Loomis Eaton Chapin, Mendes Cohen, William Weeden Cole, Herbert Wheeler Cowan, Foster Crowell, Henry Clay Derrick, Augustus Jay Du Bois, John William Eber, Emory Alexander Ellsworth, *Sir* Sandford Fleming, Alexis Henry French, Edward Gray, John Charles William

Greth, Francis Henry Hambleton, Thomas Henry Handbury, Edward Macaulay Hartrick, William Mackenzie Hughes, William Hunter, John Wykeham Jacomb-Hood, Lindsey Louin Jewel, William Cornell Jewett, Chapman Love Johnson, William Harlin Kennedy, William Byrd King, Gunardo Anfin Lange, Maxymilian Lewinson, Charles Abbott Locke, Walter Ashfield McFarland, Frank Olin Marvin, William Edwin Moore, Henry Gurney Morris, Fred Stark Pearson, Olaf Ridley Pihl, Isaac Rich, Thomas Franklin Richardson, Charles Clemons Rose, William Gardner Russell, Francis Winthrop Scarborough, Joel Herbert Shedd, John Maxwell Sherrerd, George Frederic Simpson, Clinton Fitch Stephens, Hiram Everett Terry, Morton Loudon Tower, Edmund Kimball Turner, Maurice Augustus Viele, Charles Dod Ward, Irvine Watson, William Watson, Charles Chancellor Wentworth, Edward Dana Wickes, Frank Robert Williamson.

Associate Members (12): William Frederick Allen, James Wilhelm Carpenter, Osman Fred Cole, Saint George Henry Cooke, William Gomer Davies, Harold Hansen Fitting, Louis Thomas Franklin Hickey, Albert Lloyd Hopkins, Thomas Hovenden, James Blaine Miller, Ralph Ashur Pike, Charles Ezekiel Rasinsky.

Associates (2): Francis Hopkinson Smith, John Haines Warder.

Juniors (3): Walter Cox Bowen, Harold Crosby Stevens, Frank Burns Storey.

Fellows (1): Edward Woolsey Coit.

LIBRARY

The total contents of the Library and the increase during the year, are shown in the following statement:

	Total Contents.	Increase during 1915.
Bound volumes	25 872	1 240
Unbound volumes	48 452	2 197
Specifications	7 869	181
Maps, photographs, and drawings	5 236	347
Total	87 429	3 965

Of these, 1 851 were donations received in answer to special requests; 116 were donations from publishers; 1 820 were donations received in regular course, and 178 were purchased.

The value of accessions to the Library during the year is as follows, each accession having been valued separately as received:

Donations and exchanges (estimated value)	$2 334.72
178 volumes purchased (cost)	752.08
Binding 430 volumes	512.36
Total	$3 599.16

The following amounts have been expended upon the Library during the year:

Purchases, subscriptions, and binding........	$1 264.44
Fixtures, supplies, express charges, etc.......	354.77
Total...........................	$1 619.21

The card index now contains about 100 000 cards.

During the year 100 new searches or bibliographies (containing 3 610 separate references) have been made, and copies of 33 searches made in previous years have been furnished to members and others. The total cost of this work, $944.36, has been charged to those for whom it was undertaken.

There have been 202 articles or illustrations reproduced by photography from books in the Library at a cost of $63.27.

For a little more than a year (since November, 1914), the references to current technical literature which have for many years been published monthly in *Proceedings* have been written on cards, in such form that after they have served their purpose as copy for the printer, they are filed for reference under specific headings. Thus has been started an up-to-date, and easily consulted, index to more than 100 engineering periodicals and society publications which in 13 months includes about 10 000 cards.

The total attendance in the Reading Room and Library during the year was 5 067. This does not include those who use the Library during the semi-monthly meetings.

For a year careful statistics were kept as to the number of hours spent on Library work and the cost of such work. As this information may be of interest to some of the membership, the results are stated briefly in this Report.

The Library is open for 13 hours each week-day, and the desk work therefore has to be taken care of in relays. There are six Librarians employed. Part of their time (12½%), however, is used, when necessary, in office work of the Society not connected with the Library, and this part is not included in the following statement.

The total salaries charged to Library work for the year was $6 137. About 10% of the total time was used for desk work, the time charged to this item being only that devoted to attendance on visitors. 18% was spent in cataloguing, 8½% in research work for the membership, 7% in the compilation of the published list of current technical literature, and 56½% in other Library work. This latter item includes the work preliminary to securing additions to the Library, either by purchase or gift, such as the examination of catalogues of publishers, lists of Government and State publications, and book re-views in technical periodicals; the ordering of new books; requests for donations of books, periodicals, reports, etc.; acknowledgment of donations; all the detail of making entries for accessions; preparation for the binding of volumes; care of books on the stacks; periodical inventories; preparation of book notices and other matter published in *Proceedings;* the care of the various weekly and monthly publications, and other minor details which cannot well be specified.

During the year for which these statistics were kept, 5 000 accessions were received and catalogued. These comprised the general run of accessions; bound and unbound volumes; pamphlets; periodical additions to Society publications, and other serials. The cost of cataloguing, including the writing, checking, and filing of index cards, was 22 cents for each accession.

Summing up—the total cost of the labor connected with the maintenance of the Library may be stated as follows:

Desk work	$620.51
Cataloguing	1 102.57
Research work	531.94
List of technical articles	504.94
Other Library work	3 377.19
Total cost of labor	$6 137.15

On the basis of the total number of hours devoted to Library work, the average pay of the Librarians employed by the Society has been 55.8 cents per hour.

SPECIAL COMMITTEES

There are ten Special Committees appointed to report on Engineering subjects, and the membership on these Committees consists of 85 members of the Society. In these 85, however, there are some duplications. All these Committees have been at work during the current year, and reports have been presented by all of them either to the Annual Meeting of 1915 or have been received for presentation to the Annual Meeting of 1916.

During the year $10 188.24 has been expended for the work of these Committees.

PUBLICATIONS

During the year, ten numbers of *Proceedings,* two volumes of *Transactions*, and one List of Members, have been issued.

In *Proceedings* the list of references to current engineering literature has been continued, and has covered 144 pages and contained 6 582 classified references to 111 periodicals.

The stock of the various publications of the Society, kept on hand for the convenience of members and others, now amounts to 178 125 copies, the cost of which to the Society, for paper and presswork only, has been $29 479.36.

During the year 11 664 volumes of *Transactions* have been bound for members and others in standard half-morocco and cloth bindings.

SUMMARY OF PUBLICATIONS FOR 1915.

	Issues.	Average Editions.	Total Pages.	Plates.	Cuts.
Transactions Volumes LXXVIII and LXXIX................	2	8 600	3 130	49	701
Proceedings (Monthly numbers)..	10	8 425	3 668	75	626
Constitution and List of Members.	1	8 700	339	..	1
Total...................	13	.....	7 137	124	1 328

The cost of publications has been:

For Paper, Printing, etc., *Transactions* and *Proceedings*..	$43 288.65
For Plates and Cuts..................................	3 684.68
For Boxes, Mailing Lists, Copyright, and Sundry Expenses.	960.83
For 19 000 Extra Copies of Papers and Memoirs..........	2 033.07
For List of Members..................................	2 444.02
Total....................................	$52 411.25
Deduct amount received from sale of publications........	4 247.32
Net expenditure for publications for 1915.......	$48 163.93

The net cost of publications for 1915 is $9 824.64 in excess of that for 1914, which is due to a large increase in the number of pages issued, to the increased number of plates and cuts, and to the increased edition.

INTERNATIONAL ENGINEERING CONGRESS

The International Engineering Congress, preparations for which had been in progress for several years under the auspices of this Society and of four other National Engineering Societies, was held in San Francisco, Cal., September 20th-25th, 1915, immediately after the Annual Convention. It was a gratifying success. A somewhat full account of these meetings was published in the December Number of *Proceedings*, and therefore they need only be referred to here. The Board wishes, however, to call attention to the fact that during the year the Society's funds have been called upon for a payment of about $2 500 for the support of this Congress, in addition to the payment of $2 739.88 made last year.

MEETINGS

Twenty-three meetings were held during the year, as follows: At the Annual Meeting, 1; at the Annual Convention, 2; and 20 other meetings, all of which were held at the Society House.

At these meetings there were presented twenty-one formal papers, nine of which were illustrated with lantern slides, and four lectures, all of which were illustrated with lantern slides. There were also five papers published which were not presented for discussion at any meeting of the Society. The number of members and others who took part in the preparation or discussion of these papers and lectures was 252.

The Forty-seventh Annual Convention was held at San Francisco, Cal.

The total attendance at the 23 meetings was about 5 022. The registered attendance at the Annual Meeting was 927, and at the Annual Convention, 307, but there were many guests present at all these meetings, and also members who failed to register.

At each of the ordinary semi-monthly meetings held during the year collations have been served, and these have been paid for out of the Society funds, in accordance with the action of the Annual Meeting of 1912.

MEDALS AND PRIZES

For the year ending with the month of July, 1914, prizes were awarded as follows:

The Norman Medal to Caleb Mills Saville, M. Am. Soc. C. E., for his paper entitled "Hydrology of the Panama Canal."

The J. James R. Croes Medal to J. B. Lippincott, M. Am. Soc. C. E., for his paper entitled "Tufa Cement, as Manufactured and Used on the Los Angeles Aqueduct."

The Thomas Fitch Rowland Prize to H. T. Cory, M. Am. Soc. C. E., for his paper entitled "Irrigation and River Control in the Colorado River Delta."

The James Laurie Prize to Samuel Tobias Wagner, M. Am. Soc. C. E., for his paper entitled "The Elevation of the Tracks of the Philadelphia, Germantown and Norristown Railroad, Philadelphia, Pa."

The Collingwood Prize for Juniors to J. S. Longwell, Jun. Am. Soc. C. E., for his paper entitled "Experiments on Weir Discharge."

FINANCES

During the year $10 000 was paid on the principal of the mortgage debt of the Society, thus reducing that debt from $60 000 to $50 000. On account of the increase in the expenditure for the work of Special Committees, and the increase in the amount paid for mileage to members of the Board of Direction and to members of the Nominating Committee (due to a larger attendance and not to increase in rate), it has not been possible to add to the Reserve Fund, which remains as it was last year, $90 000. It is possible that in the near future the mortgage debt may be paid in full from the Reserve Fund, thus leaving the real property of the Society unincumbered, and a balance of about $40 000 in that Fund. On the Balance Sheet attached to this Report the estimated value of the land on which the Society House is built is given as $290 000; the value of the building is based on its actual cost less an annual deduction of 2% for depreciation. The value given for the lots is based on an appraisal made by the Real Estate Board of New York, and is believed to be a very conservative statement of the present value.

The attention of members is invited to the Secretary's statement of receipts and disbursements, and to the general balance sheet which accompanies it, in which the financial condition of the Society is shown.

The reports of the Secretary and Treasurer are appended.

By order of the Board of Direction.

Chas. Warren Hunt,
Secretary.

January 17th, 1916.

REPORT OF THE SECRETARY FOR THE

To the Board of Direction of the

Gentlemen:—I have the honor to present a statement of Receipts and Disbursements for the fiscal year of the Society, ending December 31st, 1915. I also append a general balance sheet showing the condition of the affairs of the Society.

Respectfully submitted,

Chas. Warren Hunt,
Secretary.

Receipts.

Balance on hand December 31st, 1914, in Bank, Trust Company, and in hands of Secretary		$17 267.93
Entrance Fees	$11 610.00	
Current Dues	85 644.60	
Past Dues	3 899.07	
Advance Dues	29 718.62	
Certificates of Membership	499.94	
Badges	2 604.00	
Sales of Publications	4 247.32	
Library	607.18	
Annual Meeting	2 108.00	
Binding	6 027.47	
Interest	4 423.57	
Miscellaneous	323.29	
International Engineering Congress, 1915	679.25	
Clerical Help	3.60	
Work of Committees	6.34	
		$152 402.25
		$169 670.18

YEAR ENDING DECEMBER 31st, 1915.

American Society of Civil Engineers.

Disbursements.

Salaries of Officers	$15 094.44	
Mileage of Directors	5 616.12	
Mileage of Nominating Committee	860.94	
Work of Committees (Including Mileage, $3 275.28)	10 188.24	
Clerical Help	24 217.31	
Caretaking	1 861.18	
Publications	52 411.25	
Postage	7 338.50	
General Printing	2 265.52	
Office Supplies	1 219.10	
House Supplies	136.22	
Library	1 264.44	
Library Maintenance	354.77	
Badges	1 640.00	
Certificates of Membership	370.20	
Binding	7 515.05	
Prizes	258.80	
Annual Convention	941.08	
Annual Meeting	2 990.06	
Betterments	85.00	
Maintenance of House	3 033.62	
Heat, Light and Water	1 304.50	
Furniture	265.80	
Interest	2 181.11	
Current Business	2 904.55	
Petty Expenses	268.57	
International Engineering Congress, 1915	3 462.25	
Bond and Mortgage	10 000.00	
Miscellaneous	147.12	
		$160 195.74
Balance on hand, December 31st, 1915:		
In Union Trust Company	$625.17	
In Garfield National Bank	7 349.27	
In hands of Secretary	1 500.00	
		9 474.44
		$169 670.18

GENERAL BALANCE SHEET, DECEMBER 31st, 1915

Accompanying the Report of the Secretary.

Assets.			Liabilities.	
Three Lots (Actual cost, $185 406.20) (Estimated value)		$290 000.00	Dues for 1916 paid in advance	$29 718.62
Building (cost, less 2% annually for depreciation)		130 621.59	Mortgage debt	50 000.00
Furniture (cost, less 50% depreciation)		10 529.38	Interest accrued on Mortgage	166.67
Publications on hand (inventoried cost)		29 479.36	Funds invested in Society House, Lots and Library*	28 015.78
New York City non-taxable bonds (cost)		90 392.50	Herbert Stewart Library Fund	1 997.50
Library: Cash expended for books, etc.	$21 292.77		Gen. Joseph G. Swift Library Fund	998.75
Donations (estimated)	70 449.18	91 741.95	Surplus (including Reserve Fund of $87 396.25)	555 746.69
Due from Members		11 909.32		
Due from Non-Members		1 445.47		
Interest accrued on investment		1 050.00		
Cash		9 474.44		
		$666 644.01		$666 644.01

We have examined the books and accounts of the American Society of Civil Engineers, for the year ended December 31, 1915, and certify that the foregoing Balance Sheet is in accordance therewith, and, in our opinion, correctly states the condition of the Society's affairs, as shown by the books.

Marwick, Mitchell, Peat & Co.,

Chartered Accountants.

79 Wall Street, New York,

January 17th, 1916.

* Compounding Dues Fund, $11 755.00; Norman Medal Fund, $1 000.00; Rowland Prize Fund, $1 222.50; Collingwood Prize Fund, $1 000.00; Fellowship Fund, $13 038.28.

The surplus shown in the last Annual Report was $681 071.46, and the difference between that shown this year and this amount is due to a restatement of the value of the lots, building, and furniture. The present value given for the lots is based on an estimate made by the Real Estate Board of New York, and is believed to be very conservative. The cost of the building given has been reduced some $40 000 from that given last year, to allow for depreciation. Last year the actual cost of furniture was given, and this year 50% has been deducted for depreciation. This explanation is made lest someone might think that the surplus has shrunk $125 000 since last year, whereas the property, having been fully repaired, is really in better condition than it was a year ago.

REPORT OF THE TREASURER.

In compliance with the provisions of the Constitution, I have the honor to present the following report for the year ending December 31st, 1915:

Balance on hand, December 31st, 1914..................			$17 267.93
Receipts from current sources, January 1st to December 31st, 1915..			152 402.25
Payment of Audited Vouchers for Current Business, January 1st to December 31st, 1915		$150 195.74	
Payment on principal of bond and mortgage.		10 000.00	
Balance on hand, December 31st, 1915:			
In Union Trust Company.....	$625.17		
In Garfield National Bank....	7 349.27		
In hands of the Secretary.....	1 500.00	9 474.44	
		$169 670.18	$169 670.18

Respectfully submitted,

LINCOLN BUSH,
Treasurer.

NEW YORK, January 17th, 1916.

ACCESSIONS TO THE LIBRARY

(From December 2d, 1915, to January 3d, 1916)

DONATIONS*

ELEMENTS OF RAILROAD TRACK AND CONSTRUCTION.

By Winter L. Wilson, M. Am. Soc. C. E. Second Edition, Revised and Enlarged. Cloth, 7½ x 5 in., illus., 6 + 396 pp. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Limited, 1915. $2.50.

In the preface to the first edition, issued in 1908, it is stated that no attempt has been made by the author to discuss the subjects in any great detail, the general principles of track work and only that part of railroad construction with which the engineering student and young engineer may come in contact early in his experience, being presented and described. For this, the second edition, the subject-matter is said to have been largely rearranged and re-written. Two new chapters, on Practical Turnouts and on Grades, have been added, as well as many new problems and illustrations, and the data and tables, it is stated, have been brought up to date as far as practicable and consistent with the scope of the book. The Chapter headings are: History of Railroads in the United States; Permanent Way; Circular Turnouts; Practical Turnouts; Sidetracks, Yards, Terminals, Signals; Maintenance of Way; Railroad Construction; The Subgrade; Trestles; Culverts; Grades; Index.

MAINTENANCE OF WAY AND STRUCTURES.

By William C. Willard, Assoc. M. Am. Soc. C. E. Cloth, 9½ x 6½ in., illus., 21 + 451 pp. New York and London, McGraw-Hill Book Company, Inc., 1915. $4.00.

This book, it is stated, has been written to place before the railway engineer and the engineering student the best accepted practice of the day in materials and appliances, as well as organization of forces, methods of doing the work, and systems of accounting, used in the maintenance of railway track. The author, it is said, has discussed the fundamental principles and theory of the various parts of the subject, and, in each instance, has emphasized his discussion by representative examples of the practice of individual railways. The subject of signaling has been omitted as being beyond the scope of this book. Many illustrations have been included, and the subject-matter has, it is stated, been thoroughly indexed for ready reference. The Contents are: Introduction; Organization and Rules; Roadway; Ballast; Wooden Ties; Substitute Ties, Economics of Ties; The Preservation of Timber; Rails; Track Fastenings; Stresses in the Track; Design of Railway Track; Signs, Fences, and Highway Crossings; Accessories to Track; Bridges, Trestles, and Culverts; Switches, Frogs and Turnouts; Work of the Maintenance-of-Way Department; Roadway Machines, Small Tools and Supplies; Records; Accounts; Annual Program for Maintenance of Way and Structures; Index.

AMERICAN SEWERAGE PRACTICE:

Volume III, Disposal of Sewage. By Leonard Metcalf and Harrison P. Eddy, Members, Am. Soc. C. E. Cloth, 9¼ x 6½ in., illus., 13 + 851 pp. New York and London, McGraw-Hill Book Company, Inc., 1915. $6.00.

This book is the third and last volume of a series of treatises by the authors on American sewerage practice, of which Vol. I, relating to the design of sewers, and Vol. II to their construction, have already been published. In the Preface, it is stated that, in issuing Vol. III, the purpose of the authors has been twofold: First, to explain in simple non-technical language the nature of sewage and the changes that take place in it when subjected to different conditions. This explanation has been given in Chapters I to VI, inclusive. The second purpose, as stated, is to describe the modern structures and methods, with costs of construction and operation, used in the United States and Europe to produce the conditions described in the previous chapters, in order that the character of the sewage may be changed before it finds its way into some body of water. This purpose has been accomplished, it is said, in Chapters VII to XX, inclusive, which are intended primarily for designing engineers and plant operators. The book, it is said, is intended not only for engi-

* Unless otherwise specified, books in this list have been donated by the publishers.

neers, but also for sewer commissioners, sanitarians, civic economists, lawyers, and undergraduate students. The Chapter headings are: Introduction: Progressive Steps in Sewage Treatment; Meaning of Chemical Analyses; Bacteria and Their Relation to the Problems of Sewage Disposal; Plankton; Composition of Sewage; Theories of Sewage Disposal and Treatment; Sewage Disposal by Dilution; Grit Chambers; Racks, Cages and Screens; Sedimentation, Straining, and Aeration; Tanks for Sludge Digestion; Chemical Precipitation; Sludge; Contact Beds; Trickling Filters; Intermittent Sand Filtration; Irrigation and the Agricultural Utilization of Sewage and Sludge; Automatic Apparatus for Dosing; Disinfection of Sewage and Sewage Effluents; Disposal of Residential and Institutional Sewage; Appendix: Conversion Tables; Index.

SMOKE ABATEMENT AND ELECTRIFICATION OF RAILWAY TERMINALS

In Chicago: Report of the Chicago Association of Commerce Committee of Investigation on Smoke Abatement and Electrification of Railway Terminals, W. F. M. Goss, Chief Engineer. Cloth, $12\frac{1}{4}$ x $9\frac{1}{2}$ in., illus., 55 + 1 177 pp. Chicago, Rand McNally & Company, 1915. $6.00. (Donated by the Chicago Association of Commerce.)

This Committee was appointed in March, 1911, and its work, which has covered four years and in which the Committee has had the benefit of the advice and researches of experts on the subjects, is said to have been the outgrowth of a desire on the part of the citizens of Chicago for a clearer and cleaner atmosphere. In its Report the Committee has recorded the results, it is stated, of a comprehensive study of the causes and effects of air pollution in the City of Chicago and the extent to which steam locomotives have contributed thereto; it has presented the facts on which electrification of steam railroads, if decided on and if found to be technically and financially practicable, must be justified: and it has shown the advantages and disadvantages of electrification, together with an estimate of its cost. At the end of the book, there is a bibliography on the subjects of smoke abatement and air pollution, and the Committee hopes that the Report may prove of value in the solution of a difficult civic problem not only for Chicago, but for all terminal cities. The Contents are: Introduction; Part I, The Necessity for the Electrification of Chicago's Railroad Terminals; Part II, Technical Feasibility and Cost of Electrifying the Railroad Terminals of Chicago; Part III, A Study of Results Which are to be Anticipated from Electrification in Chicago; Part IV, Financial Practicability of Electrification; Part V, Summary of Conclusions with Reference to the Electrification of Railroad Terminals; Part VI, Summary of Conclusions with Reference to Atmospheric Pollution; Appendix; Index.

A TREATISE ON SAFETY ENGINEERING

As Applied to Scaffolds. The Travelers Insurance Company. Cloth, $9\frac{1}{4}$ x $6\frac{1}{2}$ in., illus., 6 + 354 pp. Hartford, Conn., The Author, 1915. $3.00.

Although used widely and by many different classes of workmen, scaffolding, it is stated, is usually badly designed, badly built, and of poor materials, with the result that men who work at considerable heights constantly risk their lives on scaffolds which are totally unfit for the purpose for which they are intended. The subject of scaffolding, with the exception of a few books dealing mainly with special scaffolds and European practice which differs from that in the United States, has been generally neglected, it is said, and in order to remedy this, the Travelers Insurance Company has prepared this book, in which various forms of scaffolding met with in American practice are illustrated and described, and the dangers involved in their use, as well as the means of reducing such dangers to a minimum, are discussed, the entire subject being treated, it is said, from the standpoint of safety. The subject-matter is based, it is stated, mainly on the results of the Company's experience and observation obtained in the course of its regular work of inspection and research, and it is hoped that a study of the subject will lead to a material improvement in the construction and operation of scaffolding and scaffolds and a consequent reduction of accidents and loss of life. The Contents are: Reality of the Scaffold Hazard; Scaffolds Considered Generally; Bricklayers' Pole Scaffold—American Practice: The Poles or Uprights, The Ledgers, The Putlogs, The Platform, Bracing, Other Safety Measures; Independent Pole Scaffold—American Practice; Lashed Scaffolds; Other Forms of Pole Scaffolds; Special Safety Features; General Features and Operations; Building with Horses; Suspended Scaffolds for Construction Work; Platform Type of Scaffold Machine, Overhead Type of Scaffold Machine, Features Common to Both Types of Suspended Scaffolds; Scaffolds of Other Kinds; Structures Similar to Scaffolds; General Counsel; Index.

THE STRUCTURE AND PROPERTIES OF THE MORE COMMON MATERIALS

Of Construction. By G. B. Upton. Cloth, 9¼ x 6 in., illus., 5 + 327 pp. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Limited, 1916. $2.50.

The aim of this book, which is said to be the outgrowth of the laboratory course in Materials of Construction for Juniors in Sibley College, is to give a theoretical discussion of the subjects of the laboratory experiments, together with the experiments themselves, in order to bring out the relations of theory and fact to engineering practice. The subject-matter is divided into two parts, the first of which is said to deal with the determination of the properties of materials by means of engineering testing and in order to teach the student how to interpret and criticize test results and to formulate standard specifications, the author, it is stated, has discussed the ordinary formulas for the calculation of stresses and deformations, stating the assumptions on which they are based, their range of validity, the factors changing the results of tests, etc., etc. The second part of the book deals, it is said, with the nature of the internal structure of materials and the control of their properties through the control of such structure. This part is in fact a short study of theoretical and applied metallography, the principles of physical chemistry concerned in heat treatment being outlined, together with many diagrams to make the relations clear. The new features of the book are said to be a method for torsion and transverse test analysis and an analysis of the general nature and detail of heat treatment presented mathematically and in diagrams. The Contents are: Part I, The Determination of the Properties of Materials: Definition and Explanation of Terms; General Nature of the Internal Structure of Materials and Action Under Loads; Tension Loading of Brittle Materials; Tension Loading of Ductile Materials; Torsion Loading; Transverse Loading; Compression Loading; Cross-Relationships of Loadings, and Combined Loads; Special Tests; Aging of Materials; Choice of Materials, etc. Part II, The Nature of Materials and Control of Their Properties: The Nature and Origin of the Structure of Alloys; The Shaping of Steel, etc.; Engineering Properties of Normal Carbon Steels as Functions of the Carbon Content; General Theory of the Heat Treatment; Engineering Heat Treatments of Carbon Steels; Cast Irons; Alloy Steels; Non-Ferrous Metals and Alloys; Cement and Cement Testing; Index.

THE BUILDING ESTIMATOR'S REFERENCE BOOK.

By Frank R. Walker. Roan, 7 x 4¾ in., illus., 5 + 612 pp. Chicago, The Author, 1915. $10.00.

In a secondary title, it is stated that this volume is a practical and thoroughly reliable reference book for contractors and estimators engaged in estimating the cost of and constructing all classes of modern buildings, including the actual labor costs and methods used in the erection of some of the present-day structures, together with all necessary material prices and labor quantities entering into the costs of all classes of buildings. The text is fully illustrated, and the costs given are stated to have been obtained from the best sources, in most cases by the author himself during the progress of the work. These costs, it is stated, have been reduced to actual hours per unit of measure, in order that they may be applied to any wage rate. The Contents are: General Conditions and Overhead Expense; Wrecking and Excavating, Caissons, etc.; Concrete for Footings and Foundations; Water and Damp Proofing; Concrete Floors and Pavements; Reinforced Concrete Construction; Brick Masonry; Rubble Work, Cut Stone, etc.; Hollow Tile Fireproofing; Rough Carpentry, Timber Framing, etc.; Mill Work and Interior Finish; Plastering; Fire Retarding Doors and Windows; Sheet Metal Work, etc.; Roofing; Exterior and Interior Marble; Interior Tiling, Floors, etc.; Glass and Glazing; Painting and Varnishing; Structural Iron and Steel; Miscellaneous and Ornamental Iron, Brass and Bronze; Miscellaneous Building Specialties; Rough and Finish Hardware; Plumbing, Sewerage and Gas Fitting; Steam and Hot Water Heating; Electric Wiring; Index.

Gifts have also been received from the following:

Alabama-State Highway Dept. 1 pam.
Am. Assoc. of Inter. Conciliation-Pan-American Div. 1 vol.
Am. Telephone & Telegraph Co. 36 pam.
Anthony, Charles. 2 bound vol., 1 pam.
Assoc. of Drainage and Levee Dists. of Illinois. 2 pam.
Baldwin, Ward. 1 pam.
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Ricker, George A. 2 pam.

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U. S.-Chf. Signal Officer. 1 bound vol.
U. S.-Coast and Geodetic Survey. 1 bound vol., 2 pam.
U. S.-Dept. of Agriculture. 33 pam.
U. S.-Dept. of the Interior. 1 vol.
U. S.-Engr. Office, Jacksonville, Fla. 1 specif.
U. S.-Engr. Office, Wheeling, W. Va. 3 specif.
U. S.-General Land Office. 1 pam.
U. S.-Geol. Survey. 1 vol., 35 pam.
U. S.-Interstate Commerce Comm. 1 bound vol., 2 pam.
U. S.-Interstate Commerce Comm.-Div. of Valuation. 1 pam.
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U. S.-Office of Public Roads. 2 pam.
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Wisconsin-Industrial Comm. 2 pam.
Wisconsin-State Superv. of Inspectors of Illuminating Oils. 2 pam.
Woodworth, R. B. 1 pam.
Wyoming-State Geologist. 3 pam.

BY PURCHASE

Tramway Track Construction and Maintenance. By R. Bickerstaffe Holt. New York and London, 1915.

Regulation of Railroads and Public Utilities in Wisconsin. By Fred L. Holmes. New York and London, 1915.

The Theory and Practice of Ore Dressing. By Edward S. Wiard. New York and London, 1915.

Heating and Ventilating Buildings: A Manual for Heating Engineers and Architects. By Rolla C. Carpenter. Sixth Edition, Revised and Rewritten. New York and London, 1915.

Steam Boiler Economy: A Treatise on the Theory and Practice of Fuel Economy in the Operation of Steam-Boilers. By William Kent. Second Edition, Revised and Enlarged. New York and London, 1915.

Test Methods for Steam Power Plants: A Reference Book for the Use of Power Station Engineers, Superintendents, and Chemists. By Edward H. Tenney. New York, 1915.

The Gas Turbine. By Norman Davey. New York, 1914.

Official Record of the First American National Fire Prevention Convention Held at Philadelphia, Pa., October 13th–18th, 1913. Compiled by Powell Evans, Editor. Philadelphia, 1914.

A Treatise on the Law of Mechanics' Liens and General Contracting of the State of New York, with Forms. By Thomas H. Ray. Albany, N. Y., 1914.

Purchasing: Its Economic Aspects and Proper Methods. By H. B. Twyford. New York, 1915.

The Corrosion of Iron: A Summary of Causes and Preventive Measures. By L. C. Wilson. New York, 1915.

The City Manager, A New Profession. By Harry Aubrey Toulmin, Jr. New York and London, 1915.

Scientific Management and Labor. By Robert Franklin Hoxie. New York and London, 1915.

A Text Book on Practical Mathematics for Advanced Technical Students. By H. Leslie Mann. New York and London, 1915.

Principles of Locomotive Operation and Train Control. By Arthur Julius Wood. New York and London, 1915.

Principles of Direct Current Machines. By Alexander S. Langsdorf. New York and London, 1915.

Theoretical Elements of Electrical Engineering. By Charles Proteus Steinmetz. Fourth Edition, Revised and Reset. New York and London, 1915.

The Principles of Dynamo Electric Machinery. By Benjamin F. Bailey. New York and London, 1915.

Valves and Valve Gears: Vol. 1, Steam Engines and Steam Turbines; Vol. 2, Gasoline, Gas and Oil Engines. By Franklin De Ronde Furman. Second Edition, Reset and Enlarged. New York and London, 1915.

The Modern Factory: Safety, Sanitation and Welfare. By George M. Price. New York and London, 1914.

The Architects' and Builders' Pocket-Book: A Handbook for Architects, Structural Engineers, Builders and Draughtsmen. By Frank E. Kidder. Compiled by a Staff of Specialists, Thomas Nolan, Editor-in-Chief. Sixteenth Edition, Rewritten. New York and London, 1916.

Filters and Filter Presses for the Separation of Liquids and Solids: From the German of F. A. Bühler, with Additional Matter Relating to the Theory of Filtration and Filtration in Sugar Factories and Refineries, by John Joseph Eastick. London, 1914.

Decisions of the Railroad Commission of the State of California; Vol. 5–6, July 1st, 1914–May 29th, 1915. Sacramento, Cal., 1915.

Bautechnische Gesteinsuntersuchungen: Mitteilungen aus dem Mineralog-geolog. Institut der Kgl. Technischen Hochschule Berlin. Von S. Hirschwald. III Jahrgang, 1912, Hefte 1 und 2. Berlin, 1912–13.

Notes on Dock and Dock Construction. By C. Colson. New York and London, 1910.

Specification and Design of Dynamo-Electric Machinery. By Miles Walker. New York and London, 1915.

Industrial and Manufacturing Chemistry: Vol. 1, Organic: A Practical Treatise. By Geoffrey Martin, Assisted by Others. Second Edition, Revised and Enlarged. New York, 1915.

King's Treatise on the Science and Practice of the Manufacture and Distribution of Coal Gas. Edited by Thomas Newbigging and W. T. Fewtrell. 3 Vol. London, 1878.

SUMMARY OF ACCESSIONS

(From December 2d, 1915 to January 3d, 1916)

Donations (including 9 duplicates)	358
By purchase	33
Total	391

MEMBERSHIP

(From December 3d, 1915, to January 6th, 1916)

ADDITIONS

MEMBERS

		Date of Membership.
BARNEY, SAMUEL EBEN. Asst. Prof., Civ. Eng., Sheffield Scientific School, Yale Univ., 346 Whitney Ave., New Haven, Conn.		Dec. 6, 1915
BISHOP, GEORGE WASHINGTON. Chf. of the Inspection Bureau, Public Service Comm. of Massachusetts, 489 Walnut St., Newtonville, Mass.		Dec. 6, 1915
BRIGGS, HARRY ALSON. Arcadia, Fla.	Assoc. M. M.	May 1, 1907 Nov. 10, 1915
LARRISON, GEORGE KIRKPATRICK. Dist. Engr., U. S. Geological Survey, and Supt. of Hydrography, Territory of Hawaii, Honolulu, Hawaii	Assoc. M. M.	July 1, 1908 Nov. 10, 1915
NASH, PAUL. City Engr., 765 Main St., Stamford, Conn.		Dec. 6, 1915
TALBOT, EARLE. Res. Engr., New York State Barge Canal Terminals, 17 Battery Pl., New York City	Jun. Assoc. M. M.	Nov. 1, 1904 Mar. 4, 1908 Sept. 21, 1915
WAHLMAN, PETRUS. Hydr. Engr., 60 Wall St., New York City		Dec. 6, 1915

ASSOCIATE MEMBERS

BARON, EDWARD VAHAN. Asst. Engr., U. S. Reclamation Service, Elephant Butte, N. Mex.		Aug. 31, 1915
BLEE, CLARENCE EARL. 226 Service Bldg., San Francisco, Cal.		Dec. 6, 1915
BOSSERT, CARL DONALD. Deputy County Surv., Columbiana County, Washingtonville, Ohio.	Jun. Assoc. M.	Oct. 31, 1911 Dec. 6, 1915
BRYAN, EVERETT N. Chf. Engr. and Asst. Gen. Supt., T. K. Beard, P. O. Box 895, Modesto, Cal.		Nov. 3, 1915
CARTER, EVLANE KEMPER. City Engr. and Supt. of Water-Works, Liberty, Mo.		Dec. 6, 1915
CATTELL, WILLIAM CLARK. County Engr., Gloucester County, Wenonah, N. J.		Dec. 6, 1915
CONWAY, NORMAN BUTLER. Engr. with Dept. of the Interior, New Hotel Arizona, Yuma, Ariz.		Dec. 6, 1915
DANIELS, ARTHUR. Asst. Engr., C., M. & St. P. Ry., 774 Murray Ave., Milwaukee, Wis.		Dec. 6, 1915
DAVIDSON, WILLIAM CLARENCE. Asst. Engr., R. J. Windrow, Court House, Waco, Tex.		Dec. 6, 1915
DENNIS, THOMAS HENRY. Res. Engr., California Highway Comm., Box 354, Colusa, Cal.		Dec. 6, 1915

ASSOCIATE MEMBERS (*Continued*)		Date of Membership.
DILLENBECK, ARVIN J. Asst. Engr., Lupfer & Remick, 594 Ellicott Sq., Buffalo, N. Y.		Aug. 31, 1915
DURFEE, JOSEPH JAY. Asst. Engr., Smith, Hauser & MacIsaac, Inc., 18 East 41st St., New York City (Res., 715 East 5th St., Brooklyn, N. Y.)	Jun. Assoc. M.	Nov. 12, 1913 Dec. 6, 1915
EDWARDS, GEORGE GARRETT. City Engr., Ennis, Tex.		Dec. 6, 1915
FLYNN, HARRY FRANKLIN. Junior Engr., U. S. Engr. Dept., P. O. Box 1809. Seattle, Wash.		Dec. 6, 1915
GREATHEAD, JOHN FRANCIS. Section Engr., Public Service Comm., First Dist.; Res., Trenton Ave., White Plains, N. Y.	Jun. Assoc. M.	Mar. 3, 1908 Nov. 3, 1915
HALL, WILLIAM NORMAN. Drainage Engr., Drainage Investigations, Office of Public Roads and Rural Eng., U. S. Dept. of Agriculture, 319 Federal Bldg., Salt Lake City, Utah		Dec. 6, 1915
HAYDEN, BEAUFORD EMMETT. Project Mgr., U. S. Reclamation Service, Newell, S. Dak.		Dec. 6, 1915
HENNING, CHARLES SUMNER, JR. Div. Engr., Ore. Short Line R. R., 1801 Rampart St., El Paso, Tex.	Jun. Assoc. M.	Dec. 3, 1913 Dec. 6, 1915
HOOVER, FREDERICK RUTHRAUFF. Gen. Agt., Canton Bridge Co., 515 New York Life Bldg., Kansas City, Mo.		Dec. 6, 1915
HUSTAD, ANDREW P. Prin. Asst. Engr., C. A. P. Turner, 4132 Aldrich Ave., South, Minneapolis, Minn.		Aug. 31, 1915
IRVIN, RICHARD. Archt. and Engr. (Irvin & Witherow), 308 Union Bank Bldg., Pittsburgh, Pa.	Jun. Assoc. M.	Sept. 6, 1910 Dec. 6, 1915
JACKMAN, ANDREW WILLIAM. First Lt., U. S. A. (*Retired*), 4714 Pitt St., New Orleans, La.		Aug. 31, 1915
JACKSON, CHARLES THOMAS. Pilot on Federal Valuation, C., M. & St. P. Ry., 173 Adams St., Spokane, Wash.		Dec. 6, 1915
JACQUES, HENRY LOUIS. Care, Spring Valley Water Co., Milpitas, Cal.		Dec. 6, 1915
JASPER, THOMAS MCLEAN. Treviddo, Liskeard, Cornwall, England		Aug. 31, 1915
JOHNSON, LOUIS RAUB. (Billings-Johnson Eng. Co.), 652 Spreckels Bldg., San Diego, Cal.		Dec. 6, 1915
KANE, IRVING PATTERSON. Asst. Dist. Engr., International Joint Comm., Henry Clay Apartments, Detroit, Mich.		Dec. 6, 1915
KELLERSBERGER, ARNOLD CHARLES. County Engr., Wilson County, Floresville, Tex.	Jun. Assoc. M.	Oct. 6, 1908 Aug. 31, 1915
KILBY, CHARLES CHRISTOPHER. Asst. Engr., The Connecticut Co., 381 Edgewood Ave., New Haven, Conn.	Jun. Assoc. M.	May 6, 1914 Dec. 6, 1915

ASSOCIATE MEMBERS (*Continued*)

		Date of Membership.
KIRBY, GEORGE LESLIE. Structural Engr. and Contr., 1338 Nicholas Bldg., Toledo, Ohio		Dec. 6, 1915
LAMBE, CLAUDE MILTON. Care, Carolina Power & Light Co., Raleigh, N. C.		Dec. 6, 1915
LEBARON, RUDOLPH WENDELL PHILLIPS. 4931 North Kimball Ave., Chicago, Ill.		Aug. 31, 1915
LEWIS, CHARLES GRANVILLE. Chf. Draftsman, Hammon Eng. Co., 433 California St., San Francisco, Cal.		Aug. 31, 1915
LIEB, VICTOR. Care, U. S. Reclamation Service, Elephant Butte, N. Mex.		Dec. 6, 1915
McCOMB, DANA QUICK. 500 West 122d St., New York City.		Dec. 6, 1915
McCURRACH, DAVID FARQUHARSEN. Asst. Engr., The Public Service Comm., Olympia, Wash.		Nov. 3, 1915
MATTIMORE, HORATIO SEYMOUR. First Asst. Engr., State Highway Dept., 49 Marshall St., Albany, N. Y.		Dec. 6, 1915
MOSER, ALBERT LEO BRECHT. With H. S. Crocker, 1125 Twenty-seventh St., Denver, Colo.	Jun. Assoc. M.	Jan. 3, 1907 Nov. 3, 1915
O'BRIEN, HARRY NEALE. Supt. of Constr., Baltimore Sewerage Comm., 605 St. Paul St., Baltimore, Md.		Dec. 6, 1915
OSGOOD, MANLEY. City Engr., Ann Arbor, Mich.	Jun. Assoc. M.	Dec. 31, 1913 Dec. 3, 1915
PARKER, ROBERT PRESTON. Care, Rd. Impvt. Dist. No. 1 of Lincoln County, Star City, Ark.		Aug. 31, 1915
PRICE, JOSEPH. Asst. Supt., U. S. Lighthouse Service, U. S. Lighthouse Office, Buffalo, N. Y.	Jun. Assoc. M.	April 4, 1911 Dec. 6, 1915
PROCTOR, ASA GLISSON. County Surv., Yolo County, Woodland, Cal.	Jun. Assoc. M.	Oct. 4, 1910 Nov. 3, 1915
REUSSNER, GEORGE HENRY. Care, U. S. Reclamation Service, Malta, Mont.		Dec. 6, 1915
ROSSELL, PAUL FRANCIS. Superv., E. I. du Pont de Nemours Powder Co., 1201 North Clayton St., Wilmington, Del.	Jun. Assoc. M.	Mar. 2, 1909 Dec. 6, 1915
SCOTT, WALTER VANDERBELT. Prin. Asst. Engr. and Estimator, Buffalo Office, Turner Constr. Co., 757 Crescent Ave., Buffalo, N. Y.	Jun. Assoc. M.	Nov. 8, 1900 Dec. 6, 1915
SHAPLEIGH, CHARLES HENRY. Asst. Engr. to the Asst. to the Pres., New Orleans & North East R. R., Vicksburg Ry., and Vicksburg, S. & Pac. Ry., 1002 Q. & C. Bldg., New Orleans, La.	Jun. Assoc. M.	June 30, 1910 Dec. 6, 1915
SHARTS, STANLEY RUSH. First Asst. Engr., County Engr.'s Office, Dayton, Ohio		Dec. 6, 1915

ASSOCIATE MEMBERS (*Continued*)

		Date of Membership.
SHERIDAN, LAWRENCE VINNEDGE. Staff Investigator, Bureau of Municipal Research, 261 Broadway, New York City.......	Jun. Assoc. M.	Mar. 5, 1912 Dec. 6, 1915
SILSBEE, JAMES ALFRED. 913 West Water St., Elmira, N. Y........................	Jun. Assoc. M.	April 4, 1911 Aug 31, 1915
SIMPSON, BURR HENRY. Deputy Engr., Ohio State Highway Dept., Cambridge, Ohio...........................		Dec. 6, 1915
STANLEY, HARVEY. Engr. of Bridges, Charlotte Harbor & North. Ry., Boca Grande, Fla.....................		Dec. 6, 1915
STANTON, HARRY SEEL. Asst. Engr., U. S. Reclamation Service, Elephant Butte, N. Mex...........................	Jun. Assoc. M.	Oct. 4, 1910 Nov. 3, 1915
WARREN, RAYMOND VERNER. Engr., Pittsburgh Div., John F. Casey Co., 229 South Millvale Ave., Pittsburgh, Pa...		Dec. 6, 1915
WILSON, EVERITT WYCHE. Gen. Supt., R. W. Hebard & Co., Inc., Box 360, Ancon, Canal Zone, Panama.........		Dec. 6, 1915
WOOD, DANA MELVIN. With Stone & Webster Eng. Corporation, Hydr. Div., 147 Milk St., Boston, Mass........		Dec. 6, 1915

JUNIORS

DUNSHEE, BERTRAM KELLOGG. Box 704, San Luis Obispo, Cal..	Nov. 3, 1915
FOGG, ALDEN KNOWLTON. Junior Engr., State Highway Comm., 302 Apollo Bldg., Peoria, Ill...............	Dec. 6, 1915
JOSEPH, JACOB. Draftsman, Div. of Designs, Public Service Comm., First Dist., 163 Schenectady Ave., Brooklyn, N. Y...	Dec. 6, 1915
MELLON, ALBERT EMERSON. Care, Edwards Constr. Co., Tampa, Fla.......................................	Aug. 31, 1915
PRAEGER, EMIL. Junior Asst. Engr., Public Service Comm., 152 Stratford Rd., Brooklyn, N. Y................	Dec. 6, 1915
QUINCY, RODGER BRADSHAW. Mgr., New Orleans Dist., Robert W. Hunt & Co., 1022 Hibernia Bank Bldg., New Orleans, La....................................	Dec. 6, 1915
RANDOLPH, SPOTTISWOODE WELLFORD. Res. Engr., Isham Randolph & Co., P. O. Box 851, Miami, Fla........	Dec. 6, 1915
REANEY, CHARLES FRANKLIN. Asst. Engr., Waterloo, Cedar Falls & No. Ry., 322 Denver St., Waterloo, Iowa....	Aug. 31, 1915
RHODES, ERIC HOUGHTON. Waratah, Toorack Rd., Brisbane, Queensland, Australia...........................	Aug. 31, 1915
SLOAN, WILLIAM GLENN. Drainage Engr., Office of Experiment Stations, U. S. Dept. of Agriculture, 439 Yates Bldg., Boise, Idaho................................	Dec. 6, 1915

JUNIORS (*Continued*)

	Date of Membership.
VAN NESS, RUSSELL ALGER. Care, Interstate Commerce Comm., 914 Karpen Bldg., Chicago, Ill.	Dec. 6, 1915
WEBSTER, JAMES MCBARRON. Junior Engr., Public Service Comm., 509 West 121st St., New York City	Dec. 6, 1915

RESIGNATIONS

MEMBERS

	Date of Resignation.
FERGUSON, GEORGE ROBERT	Dec. 31, 1915
FISK, WALTER LESLIE	Dec. 31, 1915
HAMLIN, GEORGE HERBERT	Dec. 31, 1915
HEALD, EDWARD CRESWELL	Dec. 31, 1915
JERVEY, JAMES POSTELL	Dec. 31, 1915
JOHNSON, FRANCIS ROBERT	Dec. 31, 1915
MANN, JOHN LAROY	Dec. 31, 1915
PRITCHETT, CHARLES MARCELLUS	Dec. 31, 1915
SAPP, EDWARD HOWARD	Dec. 31, 1915
SCAMMELL, JOHN KIMBALL	Dec. 31, 1915
STEWART, JOHN MUIRHEAD	Dec. 31, 1915
WETHERBEE, GEORGE ALBERT	Dec. 31, 1915
WOODRUFF, JAMES ALBERT	Dec. 31, 1915

ASSOCIATE MEMBERS

ACKENHEIL, ALFRED CURTIS	Dec. 31, 1915
ALLAN, ALEXANDER GEORGE	Dec. 31, 1915
BERRY, LESLIE GRAHAM	Dec. 31, 1915
BLACKBURN, NATHANIEL TOWNSEND	Dec. 31, 1915
BROWNELL, WILLIAM SMITH, JR.	Dec. 31, 1915
CLEAVER, PITSON JAY	Dec. 31, 1915
COLMAN, WILLIAM TUCKER	Dec. 31, 1915
COWAN, HENRY EDWIN	Dec. 31, 1915
CURRIER, ALBERT MOORE	Dec. 31, 1915
FREITAG, JOSEPH KENDALL	Dec. 31, 1915
HEWAT, HENRY JOHN	Dec. 31, 1915
HIGGINSON, JONATHAN YATES	Dec. 31, 1915
KERLINGER, WILLIAM MURRAY	Dec. 31, 1915
KIRKPATRICK, HARLOW BARTON	Dec. 31, 1915
LEE, ERNEST EUGENE	Dec. 31, 1915
MILLARD, WILLIAM JOHN	Dec. 31, 1915
OSBOURN, HENRY VAN BUREN	Dec. 31, 1915
PEABODY, LIONEL HENRY	Dec. 31, 1915
PERKINS, PHILO SACKETT	Dec. 31, 1915
PERLEY, ALAN BIGELOW	Dec. 31, 1915
SYKES, JOHN WALLACE JONES	Dec. 31, 1915

ASSOCIATE MEMBERS (*Continued*)	Date of Resignation.
TIBBETTS, FRANK LESLIE	Dec. 31, 1915
TURNEY, OMAR ASA	Dec. 31, 1915
WICKES, JOSEPH LEE	Dec. 31, 1915

JUNIORS

ANDERSON, LYTTLETON COOKE	Dec. 31, 1915
BOWDITCH, ERNEST W	Dec. 31, 1915
BROWN, OLIVER GILBERT	Dec. 31, 1915
DUFF, CARL MATHIAS	Dec. 31, 1915
GIBBLE, ISAAC OBERHOLZER	Dec. 31, 1915
GOWEN, JOHN FELLOWS	Dec. 31, 1915
GREPE, JOHN STANLEY, JR	Dec. 31, 1915
HUXTABLE, WILLIAM GUIREY	Dec. 31, 1915
L'AMOUREUX, HAROLD DANE	Dec. 31, 1915
PAUL, THEODORE LOCHART	Dec. 31, 1915
PIPER, HARRY PAUL, JR	Dec. 31, 1915
VERDERY, MARION JACKSON, JR	Dec. 31, 1915
WALKER, WILLIAM COOPER	Dec. 31, 1915
WHITMORE, CHARLES WILLIAM	Dec. 31, 1915

DEATHS

COLE, WILLIAM WEEDEN. Elected Member, October 7th, 1903; died December 20th, 1915.

DODGE, GRENVILLE MELLEN. Elected Honorary Member, March 2d, 1915; died January 3d, 1916.

ELLSWORTH, EMORY ALEXANDER. Elected Member, June 1st, 1904; died December 8th, 1915.

LOCKE, CHARLES ABBOTT. Elected Member, October 3d, 1888; died November 12th, 1915.

RICHARDSON, THOMAS FRANKLIN. Elected Member, November 4th, 1885; died December 26th, 1915.

SCARBOROUGH, FRANCIS WINTHROP. Elected Junior, September 3d, 1890; Associate Member, March 6th, 1895; Member, February 2d, 1904; died December 24th, 1915.

WATSON, IRVINE. Elected Associate Member, June 3d, 1903; Member, March 3d, 1908; died November 24th, 1915.

WICKES, EDWARD DANA. Elected Associate Member, December 3d, 1902; Member, October 2d, 1906; died June 11th, 1915.

Total Membership of the Society, January 6th, 1916, 7 911.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST

(December 2d, 1915, to January 3d, 1916)

NOTE.—*This list is published for the purpose of placing before the members of this Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS

In the subjoined list of articles, references are given by the number prefixed to each journal in this list:

(1) *Journal*, Assoc. Eng. Soc., St. Louis, Mo., 30c.
(2) *Proceedings*, Engrs. Club of Phila., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Chicago, Ill., 50c.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Gesundheits Ingenieur*, München, Germany.
(8) *Stevens Institute Indicator*, Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, 432 Fourth Ave., New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *Engineering Record*, New York City, 10c.
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(17) *Electric Railway Journal*, New York City, 10c.
(18) *Railway Review*, Chicago, Ill., 15c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 20c.
(21) *Railway Engineer*, London, England, 1s. 2d.
(22) *Iron and Coal Trades Review*, London, England, 6d.
(23) *Railway Gazette*, London, England, 6d.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *Railway Age Gazette*, Mechanical Edition, New York City, 20c.
(26) *Electrical Review*, London, England, 4d.
(27) *Electrical World*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal*, Royal Society of Arts, London, England, 6d.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium, 4 fr.
(31) *Annales* de l'Assoc. des Ing. Sortis des Ecoles Spéciales de Gand, Brussels, Belgium, 4 fr.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France, 1 fr.
(34) *Portefeuille Economiques des Machines*, Paris, France.
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(36) *Cornell Civil Engineer*, Ithaca, N. Y.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(39) *Technisches Gemeindeblatt*, Berlin, Germany, 0, 70m.
(40) *Zentralblatt der Bauverwaltung*, Berlin, Germany, 60 pfg.
(41) *Electrotechnische Zeitschrift*, Berlin, Germany.
(42) *Proceedings*, Am. Inst. Elec. Engrs., New York City, $1.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governors Island, New York Harbor, 50c.
(45) *Colliery Engineer*, Scranton, Pa., 25c.
(46) *Scientific American*, New York City, 15c.
(47) *Mechanical Engineer*, Manchester, England, 3d.
(48) *Zeitschrift*, Verein Deutscher Ingenieure, Berlin, Germany, 1, 60m.
(49) *Zeitschrift für Bauwesen*, Berlin, Germany.
(50) *Stahl und Eisen*, Düsseldorf, Germany.
(51) *Deutsche Bauzeitung*, Berlin, Germany.
(52) *Rigasche Industrie-Zeitung*, Riga, Russia, 25 kop.
(53) *Zeitschrift*, Oesterreichischer Ingenieur und Architekten Verein, Vienna, Austria, 70h.
(54) *Transactions*, Am. Soc. C. E., New York City, $12.
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(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $6.

(57) *Colliery Guardian,* London, England, 5d.
(58) *Proceedings,* Engrs.' Soc. W. Pa., 2511 Oliver Bldg., Pittsburgh, Pa., 50c.
(59) *Proceedings,* American Water-Work Assoc., Troy, N. Y.
(60) *Municipal Engineering,* Indianapolis, Ind., 25c.
(61) *Proceedings,* Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *Steel and Iron,* Thaw Bldg., Pittsburgh, Pa., 10c.
(63) *Minutes of Proceedings,* Inst. C. E., London, England.
(64) *Power,* New York City, 5c.
(65) *Official Proceedings,* New York Railroad Club, Brooklyn, N. Y., 15c.
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(71) *Journal,* Iron and Steel Inst., London, England.
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(82) *Mining and Engineering World,* Chicago, Ill., 10c.
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(84) *Le Ciment,* Paris, France.
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(86) *Engineering-Contracting,* Chicago, Ill., 10c.
(87) *Railway Engineering and Maintenance of Way,* Chicago, Ill., 10c.
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(89) *Proceedings,* Am. Soc. for Testing Materials, Philadelphia, Pa., $5.
(90) *Transactions,* Inst. of Naval Archts., London, England.
(91) *Transactions,* Soc. Naval Archts. and Marine Engrs., New York City.
(92) *Bulletin,* Soc. d'Encouragement pour l'Industrie Nationale, Paris, France.
(93) *Revue de Métallurgie,* Paris, France, 4 fr. 50.
(95) *International Marine Engineering,* New York City, 20c.
(96) *Canadian Engineer,* Toronto, Ont., Canada, 10c.
(98) *Journal,* Engrs. Soc. Pa., Harrisburg, Pa., 30c.
(99) *Proceedings,* Am. Soc. of Municipal Improvements, New York City, $2.
(100) *Professional Memoirs,* Corps of Engrs., U. S. A., Washington, D. C., 50c.
(101) *Metal Worker,* New York City, 10c.
(102) *Organ für die Fortschritte des Eisenbahnwesens,* Wiesbaden, Germany.
(103) *Mining Press,* San Francisco, Cal., 10c.
(104) *The Surveyor and Municipal and County Engineer,* London, England, 6d.
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(106) *Transactions,* Inst. of Min. Engrs., London, England, 6s.
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(108) *Iron Tradesman,* Atlanta, Ga., 10c.
(109) *Journal,* Boston Soc. C. E., Boston, Mass., 50c.
(110) *Journal,* Am. Concrete Inst., Philadelphia, Pa., 50c.
(111) *Journal of Electricity, Power and Gas,* San Francisco, Cal., 25c.
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Vol. XLII. JANUARY, 1916. No. 1.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

SECURE SUBWAY SUPPORTS

By A. B. Lueder, M. Am. Soc. C. E., and W. J. R. Wilson, Esq.

To be Presented February 16th, 1916.

Synopsis

The object of this paper is to describe the problems met in the construction of Section 13 of the Lexington Avenue Subway, New York City, to state how those problems were solved, and to give the reasons for the methods selected.

Deep and wide rock cuts made Section 13 one of the most difficult parts of the subway work. It was necessary to have an improved system of street supports in order to insure safety, and attempts were made to forsee such dangers as those caused by blasting and by rock slides. The advantages to the contractor in using massive supports and continuous steel beams are argued, and descriptions of the towers and beams are given, as well as the methods of putting them in place.

The main conclusion of the paper is that the safety of city streets during subway construction will be better guaranteed if a comprehensive design of street supports, made by competent engineers, is bid on as part of each contract.

This paper describes a street supporting system, designed by the writers and used in the construction of Section 13 of the Lexington

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

Avenue Subway, New York City, for the contractors, McMullen-Snare and Triest, during the period, 1912 to 1914. Section 13, which extends from 118th to 129th Streets, was one of the most difficult on the New York subways, owing to the varying depths—from 30 to 60 ft.—and the varying widths—from curb to curb in the shallow parts to practically the full width of street from building to building in the deep section. The corkscrew arrangement of the tracks in this section made the design of the bottom most irregular, often requiring four different levels, with a variation as great as 20 ft. in the rock bottom across the cut. The permanent structure was so irregular that practically every one of the six hundred steel bents was different. The material excavated varied from quicksand to the hardest kind of rock. The rock surface was also very irregular, being sometimes at the street surface and sometimes not found 60 ft. below. The rock itself was typical Manhattan schist and Inwood limestone, probably harder on the whole than that found in the lower part of the city, and containing many mica seams and other faults so common in New York rock. Very sharp dips transversely across the cut were frequently encountered.

In the design of the street supporting system, it was felt that the most important feature was the likelihood of New York rock to slide suddenly—a very serious danger in a deep cut. It was decided, therefore, that the supports should not rest on the rock at the sides, but on the rock bottom in the center of the cut, where they would be farthest from danger if a slide occurred, and would be directly under the street-car tracks, the heaviest load to be carried.

Any system of street support, to be effective from the standpoint of the contractor's engineers, must guarantee absolute safety to the public, must give ample working room, and must be economical as regards cost of construction and erection. In the special case, adaptability to the conditions required a most flexible scheme. A contractor cannot afford to pay damages to the public, nor does he wish that kind of advertising. The public is entitled to a design with a large factor of safety, because its members must of necessity use the streets, and are helpless to safeguard themselves against unseen dangers beneath the street surface. The contractor may feel that he can risk his money or his plant sometimes on work, but the contractor's engineer should not involve the public in any risk on designs that he makes. A subway under construction always causes

FIG. 1.—TYPICAL ROCK SLIDE, IN LEXINGTON AVENUE.

FIG. 2.—TYPICAL ROCK SLIDE, IN LEXINGTON AVENUE.

a certain amount of inconvenience to the public, especially to the business men along the route, and has never been entirely free from a certain number of minor accidents, due to concussion from blasting or irregularities in the temporary street surface. The life of wooden decking is short. The public will be glad to have the job completed in the shortest possible time.

The contractor's profits will vary to a large extent with the time he takes to do the work. Every contractor realizes that there are twice as many Sundays, nights, holidays, and bad-weather days in two years as there are in one, and these days mean expenditure without estimate. The money he pays out for watchmen and rentals, and a large part of his overhead expense, will vary according to the time required to do the work. Contracting is a peculiar business in that the profits are distinctly limited by competition, but there is no limit to the losses. The public and the contractor are agreed that subway work should be done with all speed. This is only possible with the use of the most modern plant, requiring that under the street, as above, the contractor must use hoisting engines, heavy skips and cars, and eliminate all the hand labor possible. This necessitates plenty of working room, clear of street supports. Moreover, the fewer the obstructions, the better will be the light, the greater the safety to the workmen and the greater the security because of ease of inspection and adjustment of the street supports. Instead of filling the cut with posts, each supporting an unknown load, with many wedges always uncertainly tight, there should be provided systematically-placed large supports, carrying known loads, by their size and construction better suited to take blasting shocks or to resist slides, and constantly in plain sight. Any impending danger or weakness will then immediately show itself, and, being accessible, can be easily remedied with the use of heavy machinery. In the construction of the permanent structure, for the placing of steel and concrete, the advantages of working room free from obstructions means fewer accidents, more profits, and better permanent work.

The designer, having in mind a system amply strong to carry the street loads, with supports as far removed as possible from the effects of slides, must consider how it will meet the danger due to blasting. The exact effect of a blast cannot be foretold by any one, because of the constantly changing nature of the rock which is being blasted, but experience should teach the designer to make the parts of his system exposed to blasts amply strong to withstand the maximum effect of shocks from flying rock—with intelligent blasting. Rather than strengthen the system still further to withstand careless or excessively heavy blasting, the contractor should have the blasting done by intelligent, experienced men. In a subway cut, this means taking into consideration three points: First, as always, safety, then maximum output, and then minimum of cost for labor and powder used. The blaster should be able to place and load the holes so that the rock will be thrown clear of supports against the sides of the cut, or into a clear space. The intelligent blaster will study the rock constantly, will understand where to drill the holes, and will be thoroughly conversant with the use of dynamite. It is desirable to blast as seldom as possible; that means getting a maximum quantity of muck with each blast. The nearer the blasting and excavation approach the open-quarry method, the greater will be the output, the less the powder used, and the less the number of small flying stones —all this tending to greater safety and lower cost.

The blaster, however, will be helpless if he has not a clear space, free from supports, into which he can throw large quantities of rock in safety. Such blasting brings out the rock in large pieces, and to prevent numerous interruptions to everybody from small pot-hole blasts to break them up, means must be provided for taking heavy masses of stone from the face to the dump. It is the duty of the designer to give a blaster this leeway, and to provide room and strength in his supports, so that the muck foreman may use heavy machinery to handle these large stones. On Section 13 locomotive cranes and derricks were used successfully at the face, and the supports provided stiffness and strength necessary to load heavy masses at the face by using hoisting engines and lines rigged through blocks fastened to the beam supports overhead.

Even assuming all carefulness on the part of the blaster, a designer will still have to meet, in the deeper cuts, the danger of slides in the face after a blast. This danger is small in shallow cuts, but is a most serious menace in a cut 60 ft. deep. In the side-walls small local slides may be prevented by steel pins or by shoring from the bottom with timber or concrete. Provision against large side slides in deep cuts, in the opinion of the writers, should be made in the

Fig. 3.—A Head Rock Running Across the Cut.

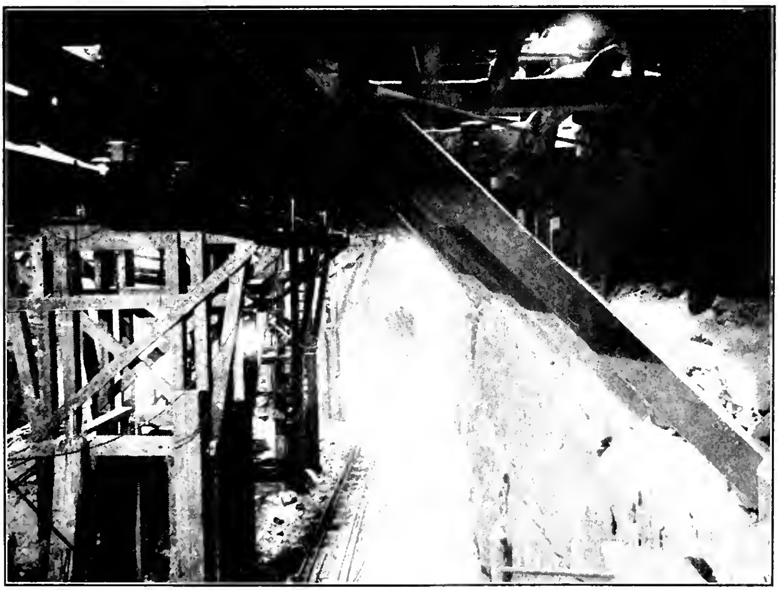


Fig. 4.—One Side of a Rock Cut, with Towers in the Center.

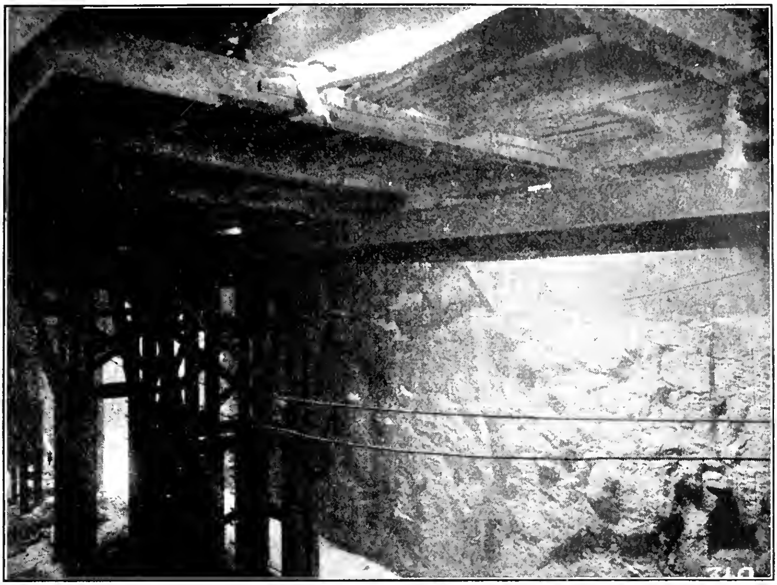


FIG. 5.—A LONG-FACE SPAN, SHOWING TOWERS, CONTINUOUS BEAMS, AND STEEL NEEDLES.

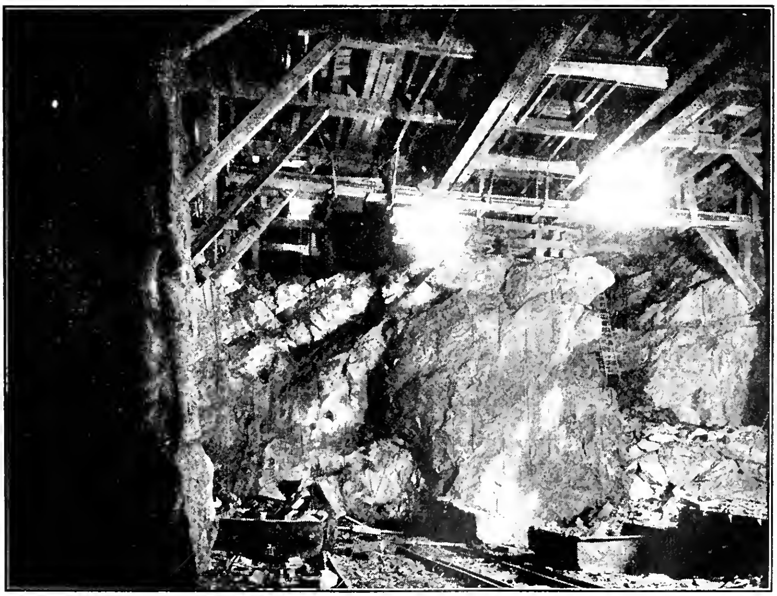


FIG. 6.—WORKING FACE UNDER LONG SPAN WITH NO POSTS.

Fig. 7.—Blasting for Deeper Level: Illustrating the Fact That, with Ample Clearance, there is Absence of Danger.

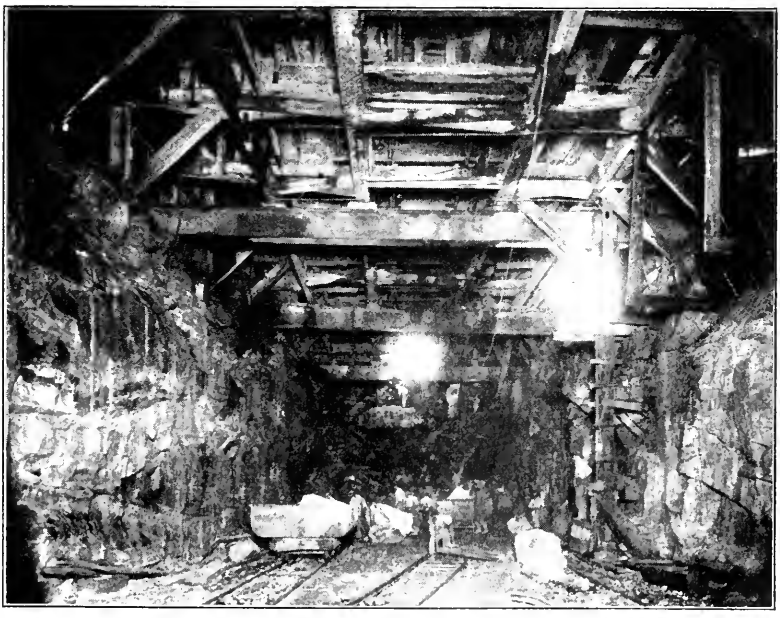


Fig. 8.—Method of Transverse Supports Under Continuous Beams in Narrow, Shallow Cut.

design of the permanent work furnished the contractors. It is a practical impossibility, owing to the numerous fissures and mica seams, to carry along a deep vertical face in New York rock. Careful inspection of the rock at the face, and search for cracks and seams on the top of the rock ahead, will sometimes give warning, but will not take care of a slide when it finally occurs. To meet this danger, the design on Section 13 provided for a span over the face long enough to allow of a support at the toe and one back of the top of the slope formed by a slide. Supports resting on the working face itself were too dangerous and too much in the way to be considered. In the deep cuts the width was so great that a transverse support spanning the cut and resting on the rock at the sides would have been expensive, and would have been useful at one point only, and, owing to the chance of slides, was considered too dangerous. In shallow and narrow cuts a transverse support, of ample strength to carry the street, and of a massive type to resist blasting shocks, was used, and rested well back on the rock at the sides. Sometimes, where the rock was uncertain, an extra support, consisting of a massive built-up post, was placed where it would cause least interference in blasting and excavation. Their size and mass (usually 24 by 36 in.) made these posts safe from chance shocks.

From the standpoint of the man who is actually building the subway, it is usually impracticable to keep the erection of the permanent structure close up to the excavation. The excavation being the largest part of the work of subway building, fast progress necessitates that the system of work shall in no way retard it. If the permanent work follows closely behind the face in a rock cut, it will interfere seriously with excavation, and the excavation will interfere seriously with the permanent work—for instance, interruptions due to blasting. The difference in elevation of the concrete floor and the excavated cut would hinder excavation, and the muck passing through the permanent work would hinder the steel workers, the carpenters, and the concrete men. Thus, the labor cost of both classes of work would increase, and, the progress being slower, the overhead cost would also increase. It has frequently happened in subway construction that the contractor, owing to changes or delays in making the working drawings, has been unable to obtain the materials for the permanent work when needed, and has been forced to keep the excavation open at points where he might have placed the permanent work. With the system adopted in Section 13, using steel supports, there could be no deterioration in the main parts to impair materially the safety of the structure.

To carry a 50-ft. length of street on a single span indicates the use of steel. If the designer provides for this span over the face, with good supports at each end, he may have a large factor of safety until one of the supports is shot out, and then he will be left with no factor of safety, and a considerable length of street may drop at once. Complete safety here requires him to have still a factor of safety in reserve by the provision of other supports back of the first ones, so that the breaking of one of these will still leave the structure safe, though that factor will be smaller, owing to the increased span. If bents are used for supports, they should be in pairs, so that one may always be in reserve; and the two bents should be thoroughly braced and tied, forming a tower with a broad base, which cannot be easily overturned. The use of two independent bents, each capable of carrying the load, gives a double factor of safety, and permits of the repairing or shifting of either bent.

To get space and clearance in the cut by combining numerous separate supports into one large one necessitates the use of long-span steel supports between towers. Short spans would not give flexibility enough for the shifting of supports. This point was very important on Section 13, because deeper levels had to be blasted out after the main excavation had been completed, and these extra cuts, sometimes 20 ft. deeper, frequently came directly under the supports. In placing concrete in floors, the extra factor of safety from the use of double bents permitted the contractor to sling to the beams above and then cut off one of the bents, and concrete to the middle of the tower. Then the short bent was wedged on the concrete, and the other bent was cut off, and the concrete placed, thus rendering it unnecessary to leave any posts or holes in the concrete. All needles were placed 10 ft. apart, so that they came exactly between two bents of the permanent steel. A 40-ft. beam was the most convenient length to use, and, as the tower bents came under the needles 10 ft. apart, this left a clear span of 30 ft., the full width of the street, to be carried by the beams with a factor of safety sufficient to allow a 40-ft. span when necessary.

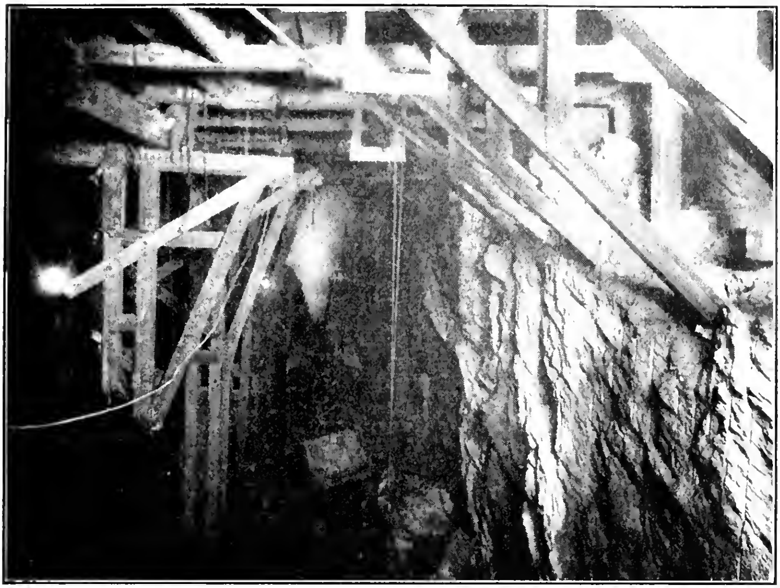


FIG. 9.—TOWER BENT, BROKEN OFF BY BLAST, SUSPENDED TO BEAMS ABOVE, WHICH ARE CARRYING SAFELY THE LOAD OVER THE EXTRA SPAN BACK TO THE NEXT SUPPORT.

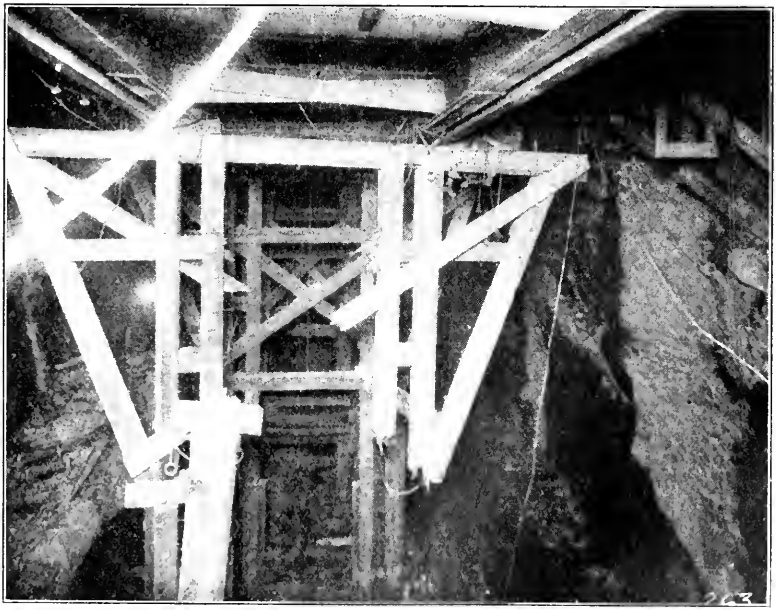


FIG. 10.—TOWER BENT, BROKEN OFF BY BLAST LASHED TO SUPPORTING BEAMS OVER THE WORKING FACE WHILE BEING REPAIRED.

FIG. 11.—TOWERS IN DEEP CUT, LOOKING DIAGONALLY ACROSS.

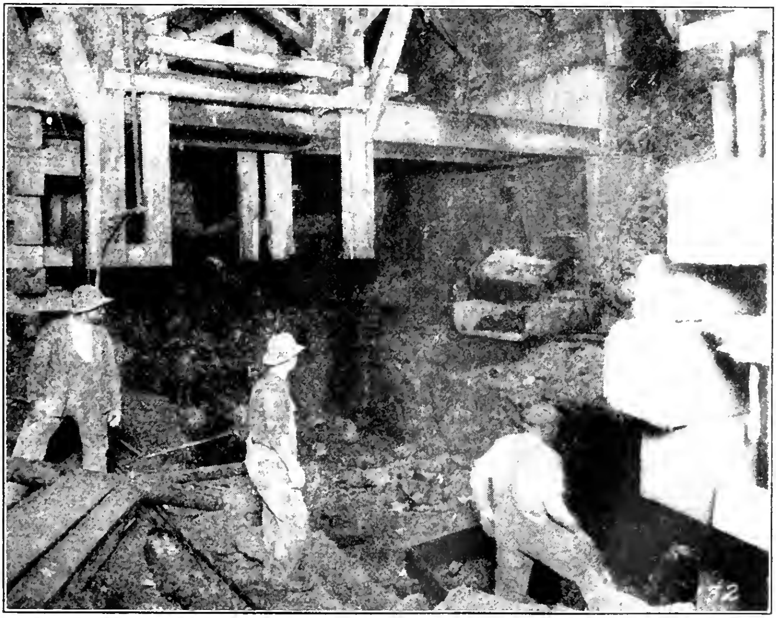


FIG. 12.—TOWER SUPPORTED WHILE EXCAVATION FOR DEEPER LEVEL IS BEING MADE UNDER IT.

If the beams had rested on bents with broken joints, the towers could not have been shifted, and this and the resulting extra strength led to the use of continuous beams. The beams were used in pairs, spliced at the joint to make a box girder, with long plates on top and bottom flanges and a wooden filler between the webs. To get the extra strength for the span needed over the long working face (55 ft. in the case of Section 13), extra pairs of beams, 100 ft. or more in length, were used on each side of the first pairs and pulled along as the face progressed. The continuous beams were carried in the center of the street, slightly outside the loads from the car tracks. It was necessary to transfer the loads from the driveway and sidewalk to these beams. The main part of the load from the driveway was carried on steel needles the ends of which were cantilevered over from the continuous beams on which they rested.

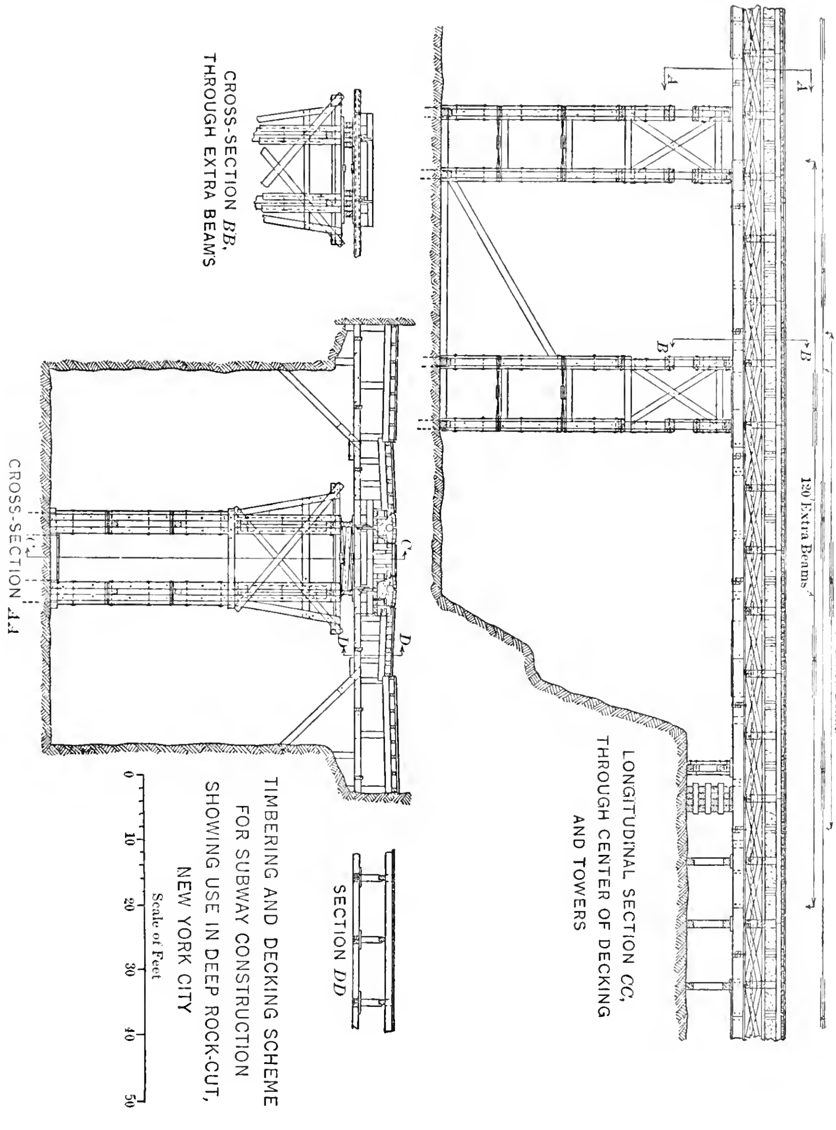
The load from the sidewalk, which, of course, was much less, was carried on wooden extensions of the steel needles. These extensions were fitted against the web and bolted securely to the steel needle with a long splice, making a joint good for bending, or for compression where it acted as a brace. For facility in posting, and to prevent the needle from rolling, it was packed on both sides with timber so that the whole needle had the shape of a square timber. These wooden plates helped in the placing of the needle by allowing easy fitting at the ends, and also served a valuable purpose, when driving a top lift in rock, in protecting the steel from flying rock while blasting. The needles acted as transverse braces across the cut to keep the whole system rigid, and were wedged against the rock or against the foundation walls of buildings. There were also provided raker struts, from the needles to niches in the rock, which helped to stiffen the structure and minimize vibration. To prevent the continuous beams from rolling, wooden bracing, with heavy turnbuckles on top and bottom of the beams, were put in every 20 ft. between each adjoining pair; similar bracing and buckles were used between adjacent needles.

On Section 13 it was found advantageous to take out a 16-ft. first lift, giving plenty of room for loading muck with machinery. A steel needle has a greater margin of safety than a wooden one at the face, and requires fewer posts. The continuous beams were spliced, and were kept a short distance back as the face advanced, permitting the use of still fewer posts, thus allowing the placing of tracks and cross-overs where they would most facilitate fast excavation.

As the towers were to carry heavy weights, they had to be well made, and to avoid depending on nails, they were accurately framed, bored, and match-marked in the contractor's yard by a competent foreman, working from a blue-print, and were carefully inspected before being sent to the cut, where the erecting gang put them together on the ground in the bottom of the cut and erected each as a unit. This made a great saving in time and lumber. The employment of high-grade timbermen in the yard and high-grade erectors in the cut specialized the work, and made it economical. The use of a long span over the face permitted a leeway of 2 or 3 days, and the choice of the most favorable opportunity during that time for the erection of the tower. The erecting was usually done at night, in order to prevent any interruption of the excavation during the day, and to permit the erecting gang to work continuously, without stopping for blasts; this also allowed the use of the heavy machinery needed in the day by the excavating gang. It was an important consideration for the contractor to have all possible lumber work done in his yard where he had at hand power tools, such as cranes for lifting heavy sticks, power saws, air augurs, etc. Left-over pieces of timber were valuable for other purposes, but in the cut they were a nuisance, and were wasted. In the yard the foreman had the blacksmith shop near him, the men had places for their tools, and they worked in daylight, without troubling about blasts or workmen over their heads.

As before stated, each tower consisted of two bents, as shown by Fig. 13, and these bents and the bracing between them were all fastened with $\frac{7}{8}$-in. bolts and dock washers. The use of bolts led to simplicity in construction and dismantling, prevented the spoiling of lumber by nails, and left nothing to the discretion of the workmen when assembling the bents. The use of $\frac{7}{8}$-in. bolts, dock washers, and a uniform width of 12 in. for lumber standardized the work, and such standards were maintained throughout the design.

Some of the advantages due to special features of the design described were peculiar to Section 13, but the writers believe that the principle of continuous beams under the car tracks, supporting steel needles carrying the street loads, is necessary in most of the subway rock cuts for safety. The principle offers great advantages



TIMBERING AND DECKING SCHEME FOR SUBWAY CONSTRUCTION SHOWING USE IN DEEP ROCK-CUT, NEW YORK CITY

FIG. 13.

in earth cuts also, because it allows keeping the heavy vertical loads off the cross-bracing, and serves to support the cross-bracing, thus replacing the transverse beams often used across an ordinary earth cut. A great advantage that the continuous beams have here is that they permit of shifting or repairing the cross-bracing without the removal of posts between sets of bracing.

One possible danger which this or any other system of street support and temporary shoring does not, and cannot, cover is the danger to buildings and their occupants along a deep rock cut from a wholesale side-slide where the cut is only about a foot from the building line. Where the danger of a local slide has shown itself in cracks or seams, it has been customary to take care of that particular spot by immediate underpinning, or by putting the building on cantilevered beams (thus taking the weight of the front wall off the edge of the cut), or by shoring of different kinds. There are cases, however, where the rock may be bad and there may be no visible evidence of the fact, as the top of the rock under the building cannot be examined. Up to the present time no general provision for safety from this danger has been made, but, in view of the fact that such a slide may take place, and of the probable large loss of life it might cause, it would seem advisable to provide for the danger, even during the time of construction, by the permanent design. This can be done, without excessive cost, by a perfectly feasible scheme. From the contractor's standpoint in bidding to-day on subways, the smaller the factor of safety the bidder intends to use in his street supporting system, the better his chances of securing the contract.

It would be conducive to greater safety if the main features of the system of support to be used were designed before letting, and bid upon as part of the contract. Systems have been designed piecemeal from the bottom up by combining the ideas of timbermen and other workmen, but the writers believe that the safety of city streets would be better guaranteed with a comprehensive design made by competent engineers. The authority and responsibility connected with the design of street supports, and the inspection of them when placed, or when shifted, or removed, should be in as few hands as possible.

The inspection of the street supports and the rock faces is of the utmost importance in subway excavation. The system which permits

FIG. 14.—CONTINUOUS BEAMS, WITH CROSS-BRACING AND TURNBUCKLES.

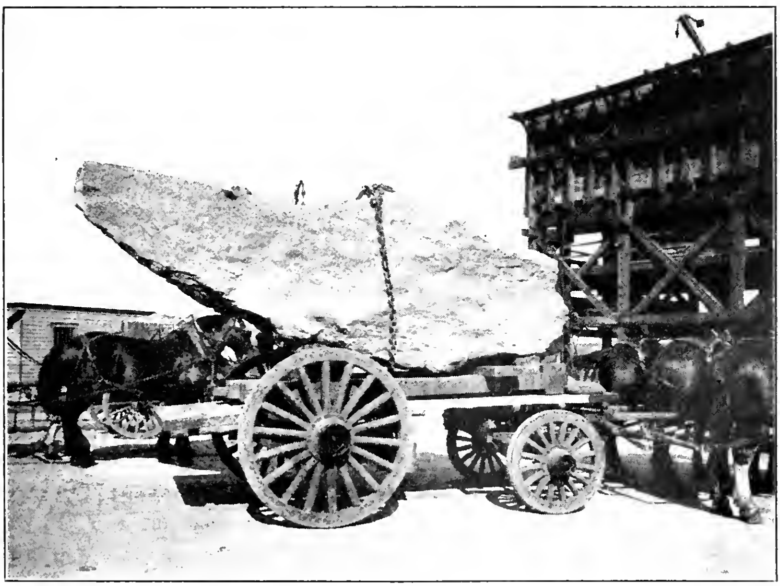


FIG. 15.—25-TON ROCK, HANDLED IN ORDINARY COURSE OF THE DAY'S WORK.

of the most rapid and thorough inspection, with the minimum of necessity for any inspection, will be the least subject to danger, and will cost the least to maintain.

There is no doubt that, with any system of supports, the decking has been and always will be a weak point, owing to the material from which it has to be constructed. It should be made amply strong for the support of the every-day traffic, but it seems unreasonable that a great extra cost, on which the contractor must estimate, should be necessary merely to make the decking safe for an occasional extraordinarily heavy or fast-moving load. In such cases the Fire Department is probably the worst offender. The contractor has no means of defense, unless the City makes the restriction. On Section 13 appeals were made to the Police Department, but it did not have the necessary authority at the time. The contractor placed signs asking that traffic move slowly, hoping for some effect from them. The decking, however, was subjected to some very heavy loads, for instance, a traction engine, a herd of elephants, and a steam shovel weighing more than 20 tons. Such loads are not ordinary traffic, and should be carried on a street without decking. The contractors themselves often use very heavy loads, but they move slowly and are but a slight risk, as they are under control. The comparatively light, fast-moving load is often more dangerous to decking than a heavy, slow-moving one, as it sometimes gets over a point, temporarily dangerous, before it can be stopped. Street-car traffic is so necessary, and so intimately connected with the welfare and convenience of the people, that no provision should be neglected to make it safe and keep it free from interruption. When a danger temporarily comes to the line, however, the street railway company and police should insist on keeping the cars out of such danger, warning of which is given by the contractors' red flags.

The desire to eliminate blasting under a city street has called forth in the technical press discussion of methods of rock excavation without the use of dynamite. Reference has usually been made to the disadvantage of these methods in that they brought out the rock in large pieces. If, however, a machine or a method can be devised to get out the rock from the face as cheaply and as quickly as at present with dynamite, the large-sized pieces would be no objection to its use with a supporting system such as adopted on Section 13.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

A STUDY OF THE BEHAVIOR OF RAPID SAND FILTERS SUBJECTED TO THE HIGH-VELOCITY METHOD OF WASHING

BY JOSEPH W. ELLMS, M. AM. SOC. C. E., AND JOHN S. GETTRUST, ESQ.

TO BE PRESENTED MARCH 1ST, 1916.

SYNOPSIS.

In this paper the writers describe and discuss the development of the high-velocity method of washing rapid sand or mechanical filters, and give a record of a series of experiments obtained in washing a small experimental filter. They also describe the corrosion of a brass wire screen which, in the construction of the filter beds of the Cincinnati, Ohio, Filtration Plant, had been placed between the gravel and sand layers, and for which some other material or some modified form of construction was necessary. Additional observations are given, showing the effect of modifying the depths and sizes of the gravel layers in certain of the Cincinnati filters after removing the brass wire screen.

The paper contains tables compiled from the experimental observations, and there are a number of diagrams and curves illustrating the effect of washing the filter with wash-water at varying rates of

NOTE.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

flow. The loss of head in the upward flow of the wash-water, produced by the strainers, varying depths and sizes of gravel, and different depths of sand, was given considerable study. The height of flotation of the sand bed during the washing process was carefully measured and recorded, and the effect of a number of factors on the height of flotation of the sand is discussed.

Historical.

In developing certain features of the design of the rapid sand filters of the Cincinnati Filtration Plant, a series of tests with an experimental filter was made between 1903 and 1905. The results obtained at that time furnished the necessary data on which the design was based. This work was carried out by one of the writers under the direction of George H. Benzenberg, Past-President, Am. Soc. C. E., and an abstract of the data secured may be found in Appendix C of Mr. Benzenberg's report as Chief Engineer of the Commissioners of Water-Works of Cincinnati, Ohio, published in 1909.

One of the principal objects of these early experiments was to determine the effect of various methods of washing the gravel and sand of the filter bed. The methods first investigated were those commonly used at that time. They consisted in forcing wash-water up through the filtering material while stirring the sand bed with mechanically rotated rakes, or by agitating with compressed air blown up through the bed before or at the time the wash-water was being applied. As a result of this preliminary work, another method of agitating the bed was developed. This consisted in forcing the wash-water up through the gravel and sand at such a rate that the sand was floated, thereby agitating and cleansing it in the same operation. This has since become known as the "high-velocity method of washing".

In these early experiments it was soon demonstrated that rotating rakes mixed the gravel and sand layers, and permitted the sand to reach the strainers and clog the openings. It was also found that compressed air blown through the bed had a disturbing influence on the two layers, and caused them to mingle to a greater or less extent. This was due in part to the type of strainers used, to the shallow depth of the gravel, and to its small size. When air and water were used together, the disturbance of the layers was much greater.

The use of wash-water at a rate of from 2.0 to 3.0 cu. ft. per sq. ft. per min. gave only slight evidence in the experimental filter that a mingling of the gravel and sand layers would result from this method of agitation. It was sufficient, however, to make it advisable to adopt precautionary measures in the design, and, with this in view, a method of forcibly holding the gravel in place by a wire-cloth screen was tried. The screen was placed between the gravel and sand layers, and was rigidly fastened. The experimental results obtained with this form of construction were so satisfactory that it was decided to place a similar screen in the large filters of the Cincinnati plant, the construction of which, at that time, was about to be commenced.

The large filter tanks of the plant were constructed with bottoms consisting of parallel hopper-shaped troughs running lengthwise of the tank, and formed by wedge-shaped concrete blocks cast in place. Spaces, 2¼ in. wide, left between the bases of adjoining rows of the parallel ridge blocks, formed the filtered water channels. These channels were covered at the top with perforated brass strainer plates. The tops of the ridges were 12 in. apart on centers, and the space from the strainer plates to these tops was filled with a graded layer of fine gravel. A brass wire-cloth with 100 meshes per sq. in. was bolted to the tops of the ridges, and rested between them on the gravel. The sand layer, having a depth of 30 in., was placed directly on the screen, as shown by Fig. 1.

The high-velocity method of washing, which had been developed experimentally, has been used with marked success during the seven years the Cincinnati Filter Plant has been in operation, and it was not until about two years after the plant was started that anything defective in the construction of the screen system was noted. It was first observed that the screen had pulled away from the bolts where it was attached to the ridges, and also at the ends of the tanks where there was lack of support for the wire-cloth and insufficient means for fastening it. Although the method of fastening the cloth was evidently mechanically defective, and although repairs were promptly made, the breaks became more frequent. It was apparent that some other factor than an inadequate method of fastening must be found to account for the constant breaking of the screen.

A careful examination of the screen showed that the brass wire was corroding, and that the short cross-wires of the cloth were broken more frequently than those running lengthwise. A slight movement of the screen, at the beginning and close of a wash, probably occurs. The first movement is upward, as the wash-water forces its way up through the gravel layer, and the second is downward, when the flow of wash-water ceases. Evidently, the short cross-wires spanning the troughs from ridge to ridge are subjected to more strain than the long wires running lengthwise of the cloth. Owing to the intermittent stresses to which the cloth is subjected and the corrosive action of the filtered water, the disintegration of the brass slowly progresses. Realizing the fact that, sooner or later, the screen would either have to be renewed or some other form of construction adopted, it was decided to undertake some experimental studies which would throw light on the problem. Having learned that, in some plants, filters washed by the high-velocity method had been constructed with deep gravel layers, and with no screen between the sand and gravel, it was decided to remove the screen from one of the large filters of the plant and study the effect of this modification of the original construction.

In order to compare the effects produced by washing with and without a brass wire-cloth screen between the gravel and sand layers, the filter bed on one side of the large filters (No. 19) of the plant was rebuilt without the screen, the other side being allowed to remain as it was built originally. As the filter tanks of this plant are constructed so that there are two separate filter beds in each filter unit, although both are operated as though there were only one bed, it was possible to make a study of the effect of the screen while other factors remained the same. The results obtained in washing the rebuilt filter indicated a greater frictional resistance to the upward flow of wash-water, and to the downward flow during filtration, on the side without the screen than on the side with the screen. The cause of this action was thought, at the time, to be due to sand working its way downward through the gravel and possibly clogging the strainer openings. Later, the real reason for the greater frictional resistance to the flow of water in the part of the filter without the screen was learned, although it was not suspected at the time.

On account of the difficulties encountered in working experimentally with these large filter units, in which large quantities of gravel and sand had to be handled and a great deal of time was required to make

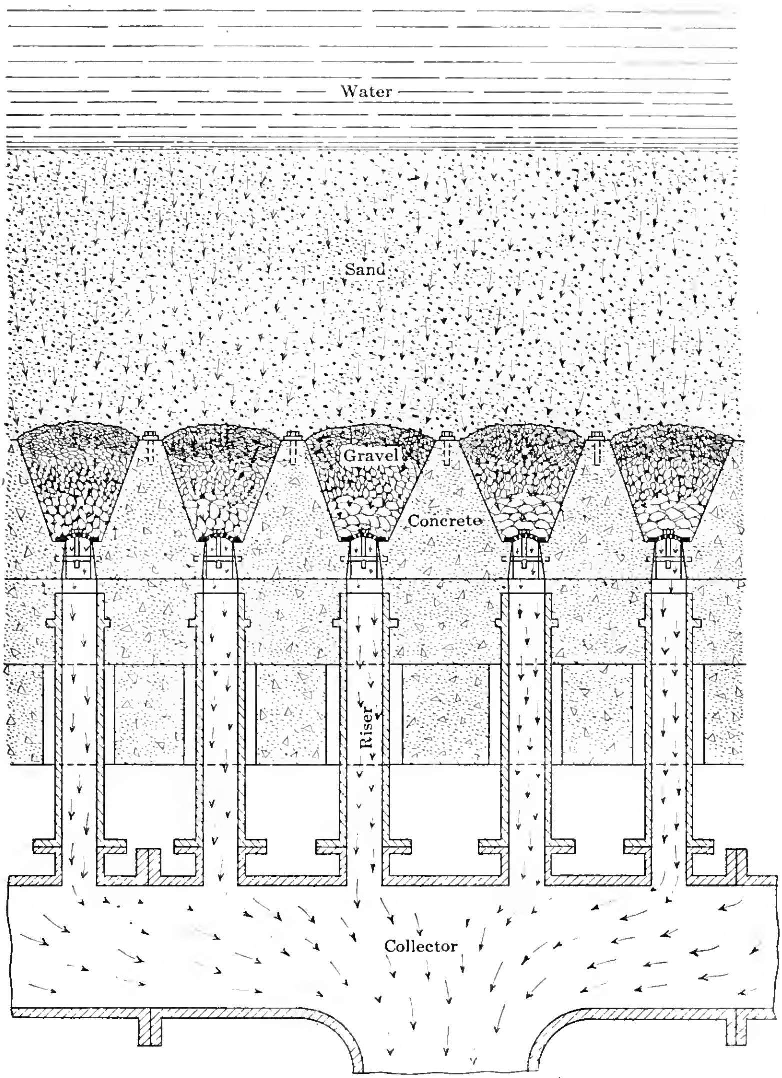


FIG. 1.

the desired changes, it was decided to construct a small experimental filter, similar to the one experimented with in 1903.

The Experimental Filter.

The experimental filter was built of 2-in. cypress lumber. It was 3 ft. square inside, and had plate-glass windows on three sides. These windows were placed so that the action of the sand and gravel would be visible. The filter was constructed so as to be an exact vertical section of the hopper-shaped troughs and strainer-plate system used in the large 4 000 000-gal. units of the Cincinnati Filtration Plant. Holes were bored at convenient points on one side of the tank, and glass gauge tubes were attached to fittings screwed into these holes. The height to which the water rose in these tubes was the measure of the pressure, in feet of water, at the point where the gauge was attached. Fig. 2 is a section through the filter showing the principal dimensions and also the location of the various gauges. The hopper-shaped troughs which hold the gravel were of the same shape and size as those in the large filters. The strainer plates used were also the same as those in the large filters. These plates were of brass, and had four rows of $\frac{3}{32}$-in. holes punched in them, each hole being $\frac{3}{4}$ in. from adjacent holes. The combined area of the openings in the strainer plates was 0.3% of the sand area of the filter. There were two gutters for draining off the wash-water, their sides being at an angle of 45° to the side of the filter tank. These gutters in the experimental filter differed from the deep gutters with straight sides which are used in the large filter units of the plant.

All the experiments were made with the water entering and leaving the filter in a reverse direction to that followed by the water during the process of filtration, that is, all experiments were made by washing the filter. As this process lifts the sand and causes it to move up and down, it is the one which is most likely to cause the gravel and sand to mix.

In measuring the flow of the wash-water to the filter, the writers used a 3-in. Worthington turbine meter which was purchased and calibrated expressly for this purpose. The wash-water was delivered under the strainer plates at four points at the bottom of the filter. The head, in feet of water at various points in the filter during the process of washing, was measured by the eight gauge glasses previously described. Back of these gauge glasses there were scales painted white, and marked off in feet and tenths, and these were set so that the zero point of each was at the same elevation. This datum line was taken arbitrarily at the inside bottom of the filter tank, all

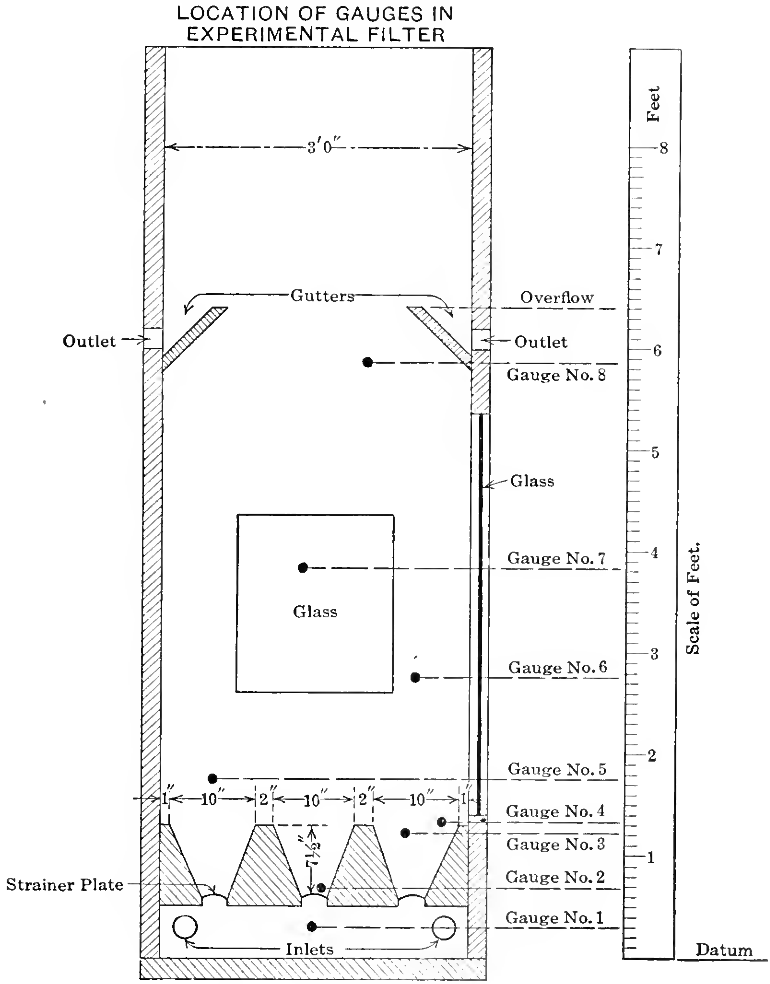


FIG. 2.

readings of the various gauges being in feet above this point. Gauge No. 1 was set under the strainer plates, at Elevation 0.3, and was approximately 0.3 ft. below them. This gauge gave a measure of the total head required to force the wash-water through the filter. Gauge

No. 2 was set immediately above the middle strainer plate, at Elevation 0.68. For a given quantity of wash-water passing through the filter, the difference in the readings between Gauges Nos. 1 and 2 gave the loss of head through the strainer plates. Gauge No. 3 was set at Elevation 1.23, so as to be just below the brass wire screen used to separate the 7½ in. of gravel from the sand. Gauge No. 4 was set at Elevation 1.32, so as to be just above the screen. Gauge No. 5 was set at Elevation 1.75, and was at the dividing line between the sand and gravel when 14 in. of gravel were used. Gauges Nos. 6, 7, and 8 were set, respectively, at Elevations 2.75, 3.82, and 5.84. Gauge No. 8 was placed so as to be above the floating sand and thus give a true measure of the elevation of the top of the water in the filter. The top of the gutters was at Elevation 6.38.

In making the tests, ordinary washed river sand was used, the mechanical analysis being given by Fig. 3. The sand had an effective size of 0.41 mm. and a uniformity coefficient of 1.41.

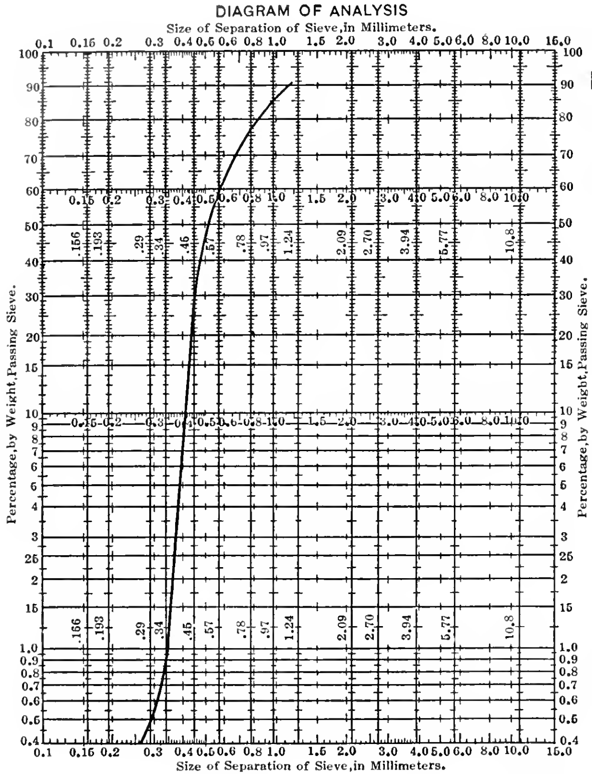
Conditions Under Which the Various Tests Were Conducted.

The writers state the results of seventeen tests with the experimental filter, and in Table 1 give the conditions under which these various tests were conducted.

TABLE 1.—Conditions Under Which Tests were Conducted.

Test No.	Depth of gravel, in inches.	Depth of sand, in inches.	Remarks.
1	None.	None.	Strainer plates only in place.
2	7½	None.	Strainer plates and gravel in place.
3	7½	None.	Brass wire screen placed over gravel.
4	7½	20	Brass wire screen between sand and gravel.
5	7½	25	Brass wire screen between sand and gravel.
6	7½	30	Brass wire screen between sand and gravel.
7	7½	20	No screen between sand and gravel.
8	7½	25	No screen between sand and gravel.
9	7½	30	No screen between sand and gravel.
10	14	None.	No screen.
11	14	20	No screen between sand and gravel.
12	14	25	No screen between sand and gravel.
13	14	30	No screen between sand and gravel.
14	18	None.	No screen.
15	18	20	No screen between sand and gravel.
16	18	25	No screen between sand and gravel.
17	18	30	No screen between sand and gravel.

Note.—For each of these tests, a tabulation of the data may be found on the "test sheet" having the same number as that of the test; and plotted curves of the data will be found on the "curve sheets" having numbers corresponding to those of the tests. The details of Tests Nos. 5, 8, 12, and 16, however, are omitted in the paper, as they show the conditions in washing with a depth of 25 in. of sand. The conditions of washing for 20 and 30 in. are shown in the other tests, and there are no marked characteristics for the 25-in. depth which are not indicated by the tests for the 20 and 30-in. depths.



CINCINNATI, OHIO

MECHANICAL ANALYSIS OF FILTERING MATERIAL

No. of Sample EXPERIMENTAL FILTER

Location of Deposit AVERAGE (ENTIRE DEPTH)

Date of Collection

Date of Analysis

Remarks

Size of Separation of Sieve No.	Mm.	Weight Passing Sieve, in Grammes	Percentage, by Weight, Passing Sieve
2	10.8		
4	5.77		
6	3.94		
8	2.70		
10	2.09		
16	1.24		
20	0.97	85.0	85.0
24	0.78	77.0	77.0
30	0.57	59.0	59.0
40	0.45	26.0	26.0
50	0.34	1.0	1.0
60	0.29	0.5	0.5
80	0.193	0.2	0.2
100	0.156	0.0	0.0

Amount examined 100 *Grammes*

Effective Size 10 per cent finer than 0.41 *mm.*

60 per cent finer than 0.58 *mm.*

Uniformity Coefficient 1.41

Per cent finer than 0.20 mm. =

" " " " 0.25 mm. =

" " " " 0.85 mm. =

Fig. 3.

When a depth of 7½ in. of gravel was used, it was graded and placed as follows:

First layer: 1-in. layer (hand-placed) that passed a 1-in. mesh sieve and was held on a ½-in. mesh sieve;

Second layer: 6 in. of gravel that passed through a ½-in. mesh sieve and was held on a sieve with 10 meshes per lin. in.;

Third layer: ½-in. layer of gravel that passed a 10-mesh sieve and was held on a sieve with 12 meshes per lin. in.

This arrangement of the gravel was the same as in the original construction of the 4 000 000-gal. filter units.

When a depth of 14 in. of gravel was used, it was graded and placed as follows:

First layer: 2 in. of gravel (hand-placed) that was held on a 1-in. mesh screen but would pass through a 2-in. mesh screen;

Second layer: 2 in. of gravel that passed a 1-in. mesh screen and was held on a ¾-in. mesh screen;

Third layer: 3 in. of gravel that passed a ¾-in. mesh screen and was held on a ½-in. mesh screen;

Fourth layer: 3 in. of gravel that passed a ½-in. mesh screen and was held on a ¼-in. mesh screen;

Fifth layer: 4 in. of gravel that passed a ¼-in. mesh screen.

When a depth of 18 in. of gravel was used, it was graded and placed as follows:

First layer: 2 in. of gravel that was held on a 1-in. mesh screen but would pass through a 2-in. mesh screen;

Second layer: 3 in. of gravel that passed a 1-in. mesh screen and was held on a ¾-in. mesh screen;

Third layer: 3 in. of gravel that passed a ¾-in. mesh screen and was held on a ½-in. mesh screen;

Fourth layer: 4 in. of gravel that passed a ½-in. mesh screen and was held on a ¼-in. mesh screen;

Fifth layer: 6 in. of gravel that passed a ¼-in. mesh screen.

Method of Making Observations.

In making the tests, a 2-in. gate-valve, which admitted the wash-water under the strainer plates, was gradually opened enough to give sufficient upward velocity to the wash-water to cause flotation of all the sand in the filter. Readings of the eight gauges were then recorded as shown by the height of the water in them, and readings of the water meter were taken at the start and finish of the observations made with a certain rate of flow of the wash-water. The time interval between the readings of the meter was taken with a stop-watch. The height to which the sand floated during the washing process, above that which it occupied when the filter was idle, was measured by observations through the plate-glass windows. Measurements were also made by using small metal cups, open at the top and arranged on a steel plate so that the top of the lowest cup was 2 in. from the bottom of the plate, the top of each cup being 2 in. above the top of the next lower one. The arrangement of this apparatus is shown by Fig. 4.

When starting a test, the bottom edge of the sand catcher was placed level with the surface of the sand as it lay in its normal position after being washed and hydraulically graded. The height to which the sand floated could be determined within less than 2 in. by withdrawing the cups from the filter at the close of the test and noting the height, in inches, from the bottom edge of the plate to the top of the highest cup which was filled with sand. During most of the tests, the water was clear enough to read the height of the sand without withdrawing the cups, and it was possible to interpolate readings of the height between adjacent cups.

In conducting a test, the upward velocity of the wash-water was increased step by step, readings being taken as previously stated, and was finally increased to about 2.1 ft. per min., the latter rate being as great as it was possible to obtain. The supply of wash-water was obtained from the same source as that which furnishes the wash-water for the 4 000 000-gal. units of the filter plant. These large filter units are washed with an upward velocity of the wash-water of 2 ft. per min. This rate is calculated from the area of the filter unit and the quantity of water used per minute in washing. No allowance is made for the space taken by the sand particles or by the wash-water troughs.

The wash-water used was filtered water which had been raised by centrifugal pumps to an elevated reservoir. This reservoir has an overflow, thus making it possible to operate one of the centrifugal pumps continuously and thereby maintain a constant head in the wash-water tank while making tests with the experimental filter. The water from the overflow of the wash-water reservoir passes back through a pipe line to the suction well of the pumps. The washing of the large filter units was suspended while a test was being made with the

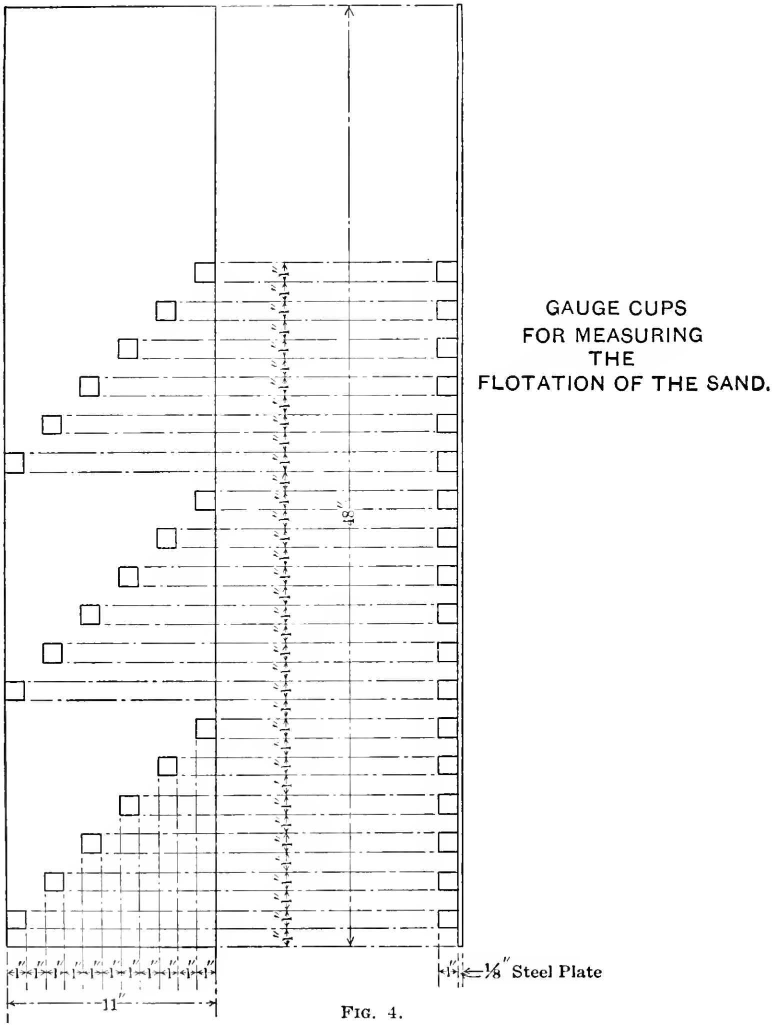


FIG. 4.

experimental filter, so that there would be no variations in the upward velocities of the wash-water in the latter on account of changes in the acting head, except those purposely made by the person conducting the test.

During all the tests the effect on the sand and gravel was observed carefully through the plate-glass windows. The behavior of the sand and gravel at the plane dividing them was noted, particularly during the process of washing and when the filter was emptied of water by opening a drain valve connected to that portion which was under the strainer plates.

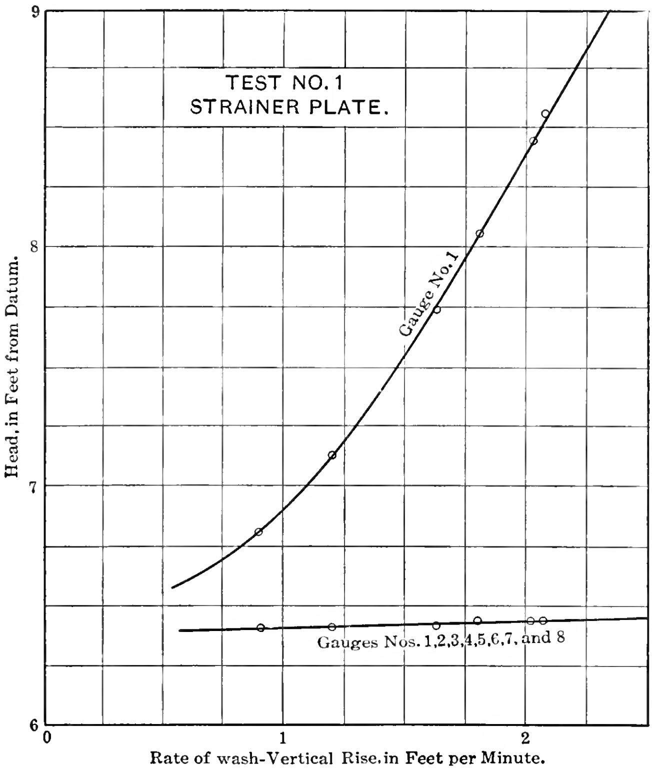


FIG. 5.

DISCUSSION OF THE EXPERIMENTAL DATA.

Comparing the curves for Tests Nos. 2 and 3 (Figs. 6 and 7), which were plotted from the results obtained with the use of 7½ in. of gravel in both tests, but with the addition of the brass screen in Test No. 3 and without it in Test No. 2, it is evident that the introduction of the screen added very little to the head necessary to force the water through the filter. The head, as recorded by Gauge No. 3, which was directly below the screen, was identical for the two tests.

Gauges Nos. 1 and 2 showed a head approximately 0.02 ft. higher in Test No. 3 made with the screen, than in Test No. 2 made without the screen. The screen used was new, and the openings between the wires had not become plugged up with gravel.

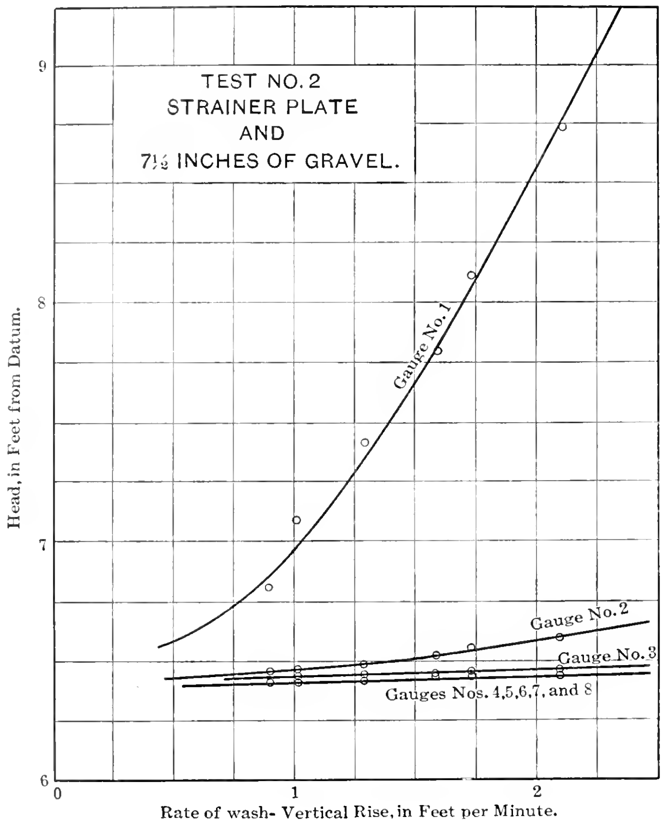


FIG. 6.

A comparison of the curves plotted from the data obtained in Tests Nos. 4, 6, 7, and 9 (Figs. 9 to 11, inclusive) in which 20 and 30 in. of sand were used, both with and without the screen, shows that, for the same depth of sand, the total head necessary to force the wash-water through the filter, at equal upward velocities, was practically the same with or without the screen. Gauges Nos. 2 and 3 showed a slightly increased loss of head in the three tests without the screen over those with the screen. The tests with the screen were conducted previously to those without the screen. It is probable that, in walking over the gravel when the screen was removed, the gravel around the gauge outlets was disturbed and became lodged in such a position as to cause the upward velocity of the wash-water to increase slightly the reading of these two gauges.

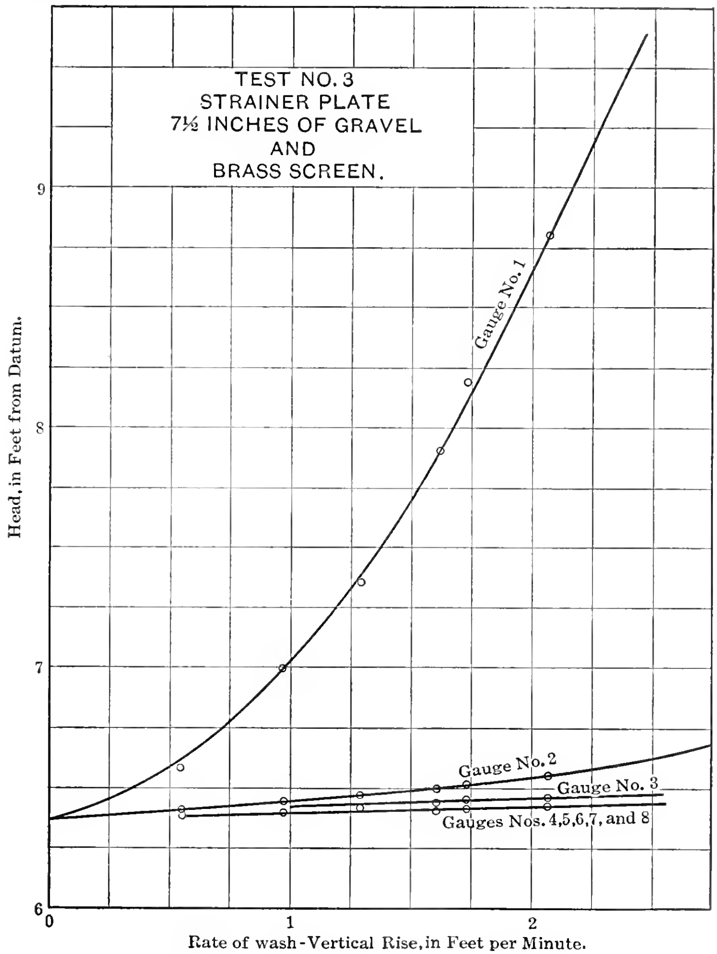


FIG. 7.

In Test No. 5 (the curves for which are not reproduced herein), with an upward velocity of the wash-water of 1.6 ft. per min., the pressure on Gauge No. 7 began to increase rapidly. At this point the

Test No. 1.

Conditions : Strainer Plates, Only, in Place.

Reading No.	Upward velocity of wash-water, in feet per minute.	Rise of sand, in inches.	Gauge Reading. No. 1.	No. 2	No. 3.	No. 4.	No. 5.	No 6.	No. 7.	No. 8.
1	0.9	....	6.81	6.4	6.4	6.4	6.4	6.4	6.4	6.4
2	1.2	....	7.12	6.41	6.41	6.41	6.41	6.41	6.41	6.41
3	1.63	....	7.74	6.42	6.42	6.42	6.42	6.42	6.42	6.42
4	1.81	....	8.06	6.43	6.43	6.43	6.43	6.43	6.43	6.43
5	2.03	....	8.43	6.43	6.43	6.43	6.43	6.43	6.43	6.43
6	2.09	....	8.55	6.43	6.43	6.43	6.43	6.43	6.43	6.43

Test No. 2.

Conditions : Strainer Plates, and $7\frac{1}{2}$ in. of Gravel in Place.

Reading No.	Upward velocity of wash-water, in feet per minute.	Rise of sand, in inches.	Gauge Reading. No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8
1	0.81	....	6.81	6.45	6.41	6.40	6.40	6.40	6.40	6.40
2	1.02	....	7.07	6.47	6.43	6.41	6.41	6.41	6.41	6.41
3	1.30	....	7.41	6.49	6.44	6.42	6.42	6.42	6.42	6.42
4	1.60	....	7.79	6.52	6.45	6.43	6.43	6.43	6.43	6.43
5	1.74	....	8.12	6.55	6.46	6.43	6.43	6.43	6.43	6.43
6	2.11	....	8.73	6.58	6.47	6.43	6.43	6.43	6.43	6.43

Test No. 3.

Conditions : Strainer Plates, $7\frac{1}{2}$ in. of Gravel, and Brass Screen in Place.

Reading No.	Upward velocity of wash-water, in feet per minute.	Rise of sand, in inches.	Gauge Reading. No. 1.	No. 2	No. 3.	No. 4.	No. 5.	No 6.	No. 7.	No. 8.
1	0.56	....	6.59	6.41	6.39	6.39	6.39	6.39	6.39	6.39
2	0.98	....	7.0	6.45	6.41	6.41	6.41	6.41	6.41	6.41
3	1.29	....	7.36	6.47	6.42	6.41	6.41	6.41	6.41	6.41
4	1.62	....	7.88	6.50	6.44	6.42	6.42	6.42	6.42	6.42
5	1.73	....	8.18	6.52	6.45	6.43	6.43	6.43	6.43	6.43
6	2.08	....	8.80	6.56	6.46	6.43	6.43	6.43	6.43	6.43

Test No. 4.

Conditions : Strainer Plates, $7\frac{1}{2}$ in. of Gravel, Brass Screen, and 20 in. of Sand in Place.

Reading No.	Upward velocity of wash-water, in feet per minute.	Rise of sand, in inches.	Gauge Reading. No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8
1	0.83	1.7	8.13	7.75	7.68	7.59	7.33	6.57	6.40	6.40
2	1.08	3.0	8.44	7.77	7.74	7.65	7.38	6.62	6.41	6.41
3	1.26	4.0	8.69	7.79	7.71	7.67	7.39	6.65	6.41	6.41
4	1.46	4.8	9.0	7.82	7.78	7.68	7.40	6.68	6.41	6.41
5	1.73	6.0	9.39	7.84	7.79	7.70	7.40	6.70	6.42	6.42
6	2.04	7.5	10.0	7.9	7.83	7.72	7.42	6.74	6.43	6.43

Test No. 6.

Conditions: Strainer Plates, $7\frac{1}{2}$ in. of Gravel, Brass Screen, and 30 in. of Sand in Place.

Reading No.	Upward velocity of wash-water, in feet per minute.	Rise of sand, in inches.	Gauge Reading. No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.
1	1.08	3	9.16	8.43	8.38	8.31	8.03	7.25	6.48	6.41
2	1.28	5	9.45	8.48	8.43	8.35	8.05	7.28	6.55	6.41
3	1.42	6	9.68	8.52	8.45	8.38	8.08	7.30	6.60	6.42
4	1.60	7	9.93	8.54	8.48	8.4	8.09	7.32	6.65	6.42
5	1.73	9	10.19	8.58	8.50	8.4	8.12	7.37	6.70	6.43
6	2.05	11	10.72	8.65	8.53	8.42	8.14	7.40	6.78	6.43

Test No. 7.

Conditions: Strainer Plates, $7\frac{1}{2}$ in. of Gravel, and 20 in. of Sand. Without Brass Screen.

Reading No.	Upward velocity of wash-water, in feet per minute.	Rise of sand, in inches.	Gauge Reading No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.
1	0.78	1.8	8.13	7.85	7.72	7.61	7.34	6.55	6.40	6.40
2	1.09	3.3	8.50	7.89	7.80	7.67	7.37	6.60	6.41	6.41
3	1.26	4.0	8.72	7.92	7.83	7.68	7.38	6.63	6.41	6.41
4	1.43	5.0	8.91	7.94	7.86	7.70	7.39	6.67	6.42	6.42
5	1.69	6.3	9,38	7.98	7.90	7.73	7.40	6.70	6.42	6.42
6	2.04	8.0	10.01	8.03	7.94	7.73	7.43	6.76	6.43	6.43

Test No. 9.

Conditions: Strainer Plates, $7\frac{1}{2}$ in. of Gravel, and 30 of Sand. Without Brass Screen.

Reading No.	Upward velocity of wash-water, in feet per minute.	Rise of sand, in inches.	Gauge Reading No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.
1	0.65	2	8.73	8.51	8.41	8.30	8.03	7.20	6.43	6.40
2	0.93	4	9.14	8.60	8.51	8.36	8.08	7.32	6.58	6.41
3	1.29	6	9 45	8.64	8.56	8.38	8,08	7.33	6.66	6.41
4	1.53	8	9.80	8.69	8.60	8.40	8.09	7.34	6.71	6.42
5	1.78	10	10.17	8.73	8.63	8.42	8.11	7.38	6.77	6.43
6	2.03	12	10.65	8.76	8.65	8.43	8.12	7.41	6.84	6.43

Test No. 10.

Conditions: Strainer Plates and 14 in. of Gravel.

Reading No.	Upward velocity of wash-water, in feet per minute.	Rise of sand, in inches.	Gauge Reading No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.
1	0.83	....	6.92	6.50	6.47	6.47	6.40	6.40	6.40	6.40
2	1.14	....	7.31	6.54	6.51	6.50	6.41	6.41	6.41	6.41
3	1.39	....	7.71	6.58	6.54	6.53	6.41	6.41	6.41	6.41
4	1,64	....	8.13	6.63	6.57	6.56	6.42	6.42	6.42	6.42
5	1.83	....	8.50	6.67	6.60	6.58	6.42	6.42	6.42	6.42
6	2.07	....	9.00	6.73	6.64	6.61	6.43	6.43	6.43	6.43

Test No. 11.
Conditions: Strainer Plates, 14 in. of Gravel, and 20 in. of Sand.

Reading No.	Upward velocity of wash-water, in feet per minute.	Rise of sand, in inches	Gauge Reading. No. 1	No. 2.	No. 3.	No. 4.	No. 5.	No 6.	No. 7.	No. 8.
1	0.79	1.5	8.23	7.84	7.82	7.81	7.75	6.93	6.40	6.40
2	1.03	2.8	8.58	7.92	7.89	7.88	7.76	6.97	6.41	6.41
3	1.25	4.3	8.94	7.99	7.94	7.93	7.78	7.00	6.42	6.42
4	1.44	5.3	9.29	8.04	7.99	7.98	7.79	7.03	6.45	6.42
5	1.65	6.5	9.68	8.10	8.03	8.01	7.80	7.05	6.49	6.43
6	2.08	9.0	10.51	8.19	8.10	8.07	7.82	7.09	6.56	6.43

Test No. 13.
Conditions: Strainer Plates, 14 in. of Gravel, and 30 in. of Sand.

Reading No.	Upward velocity of wash-water, in feet per minute.	Rise of sand, in inches.	Gauge Reading. No. 1.	No. 2.	No. 3	No. 4.	No. 5	No. 6.	No. 7.	No. 8.
1	0.68	2	8.80	8.51	8.50	8.49	8.40	7.63	6.78	6.40
2	0.95	4	9.14	8.62	8.59	8.58	8.44	7.67	6.88	6.41
3	1.15	6	9.44	8.69	8.66	8.65	8.46	7.70	6.93	6.41
4	1.36	8	9.77	8.76	8.71	8.70	8.47	7.71	6.98	6.42
5	1.48	9	9.97	8.79	8.74	8.72	8.48	7.71	7.00	6.42
6	2.02	14	11.11	8.92	8.85	8.82	8.51	7.78	7.13	6.43

Test No. 14.
Conditions: Strainer Plates and 18 in. of Gravel.

Reading No.	Upward velocity of wash-water, in feet per minute.	Rise of sand, in inches	No. 1	No. 2.	No. 3.	No. 4.	No. 5.	No 6.	No. 7.	No. 8.
1	0.74	....	6.92	6.50	6.47	6.47	6.45	6.39	6.40	6.40
2	1.18	....	7.61	6.58	6.55	6.54	6.49	6.41	6.41	6.41
3	1.44	....	8.14	6.64	6.59	6.58	6.51	6.41	6.41	6.41
4	1.70	....	8.69	6.69	6.63	6.61	6.54	6.42	6.42	6.42
5	1.93	....	9.08	6.73	6.66	6.65	6.56	6.42	6.42	6.42
6	2.05	....	9.60	6.78	6.70	6.68	6.57	6.43	6.43	6.43

Test No. 15.
Conditions: Strainer Plates, 18 in. of Gravel, and 20 in. of Sand.

Reading No.	Upward velocity of wash-water, in feet per minute.	Rise of sand, in inches.	No. 1.	No. 2.	No. 3	No. 4.	No. 5	No. 6.	No. 7.	No. 8.
1	0.86	2	8.50	8.03	8.01	8.00	7.94	7.26	6.47	6.40
2	1.21	4	9.02	8.13	8.10	8.09	8.00	7.30	6.57	6.41
3	1.55	6	9.62	8.22	8.18	8.17	8.00	7.31	6.65	6.42
4	1.78	8	10.10	8.30	8.23	8.22	8.10	7.32	6.69	6.42
5	1.94	9	10.46	8.35	8.28	8.26	8.12	7.33	6.72	6.43
6	2.04	10	10.75	8.38	8.31	8.28	8.14	7.34	6.74	6.43

Test No. 17.
Conditions: Strainer Plates, 18 in. of Gravel, and 30 in. of Sand.

Reading No.	Upward velocity of wash-water, in feet per minute.	Rise of sand, in inches	No. 1	No. 2.	No. 3.	No. 4.	No. 5.	No 6.	No. 7.	No. 8.
1	0.74	2	8.95	8.62	8.61	8.60	8.55	7.93	7.08	6.40
2	1.13	6	9.56	8.81	8.78	8.77	8.69	7.99	7.20	6.41
3	1.46	10	10.13	8.93	8.88	8.87	8.77	8.02	7.27	6.42
4	1.68	13	10.55	9.01	8.94	8.93	8.80	8.04	7.30	6.42
5	1.83	15	10.87	9.07	9.00	8.98	8.84	8.06	7.34	6.43
6	2.02	17	11.32	9.14	9.06	9.04	8.88	8.08	7.39	6.46

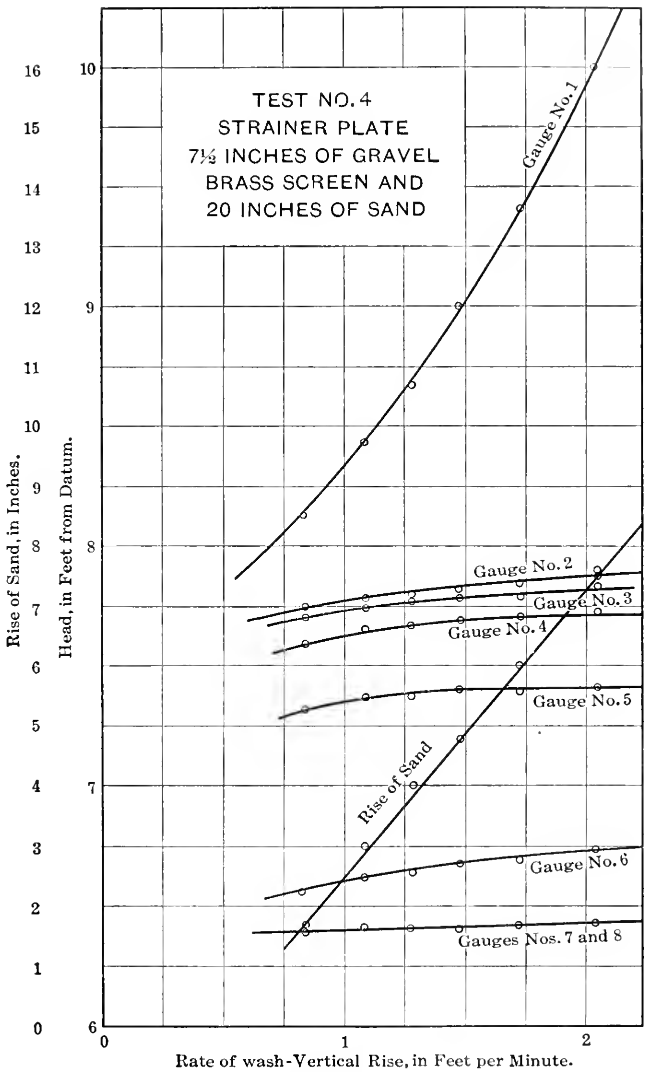

TEST NO. 4
STRAINER PLATE
7½ INCHES OF GRAVEL
BRASS SCREEN AND
20 INCHES OF SAND
Gauge No. 1
Gauge No. 2
Gauge No. 3
Gauge No. 4
Gauge No. 5
Rise of Sand
Gauge No. 6
Gauges Nos. 7 and 8
Rise of Sand, in Inches.
Head, in Feet from Datum.
Rate of wash-Vertical Rise, in Feet per Minute.
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

Fig. 8.

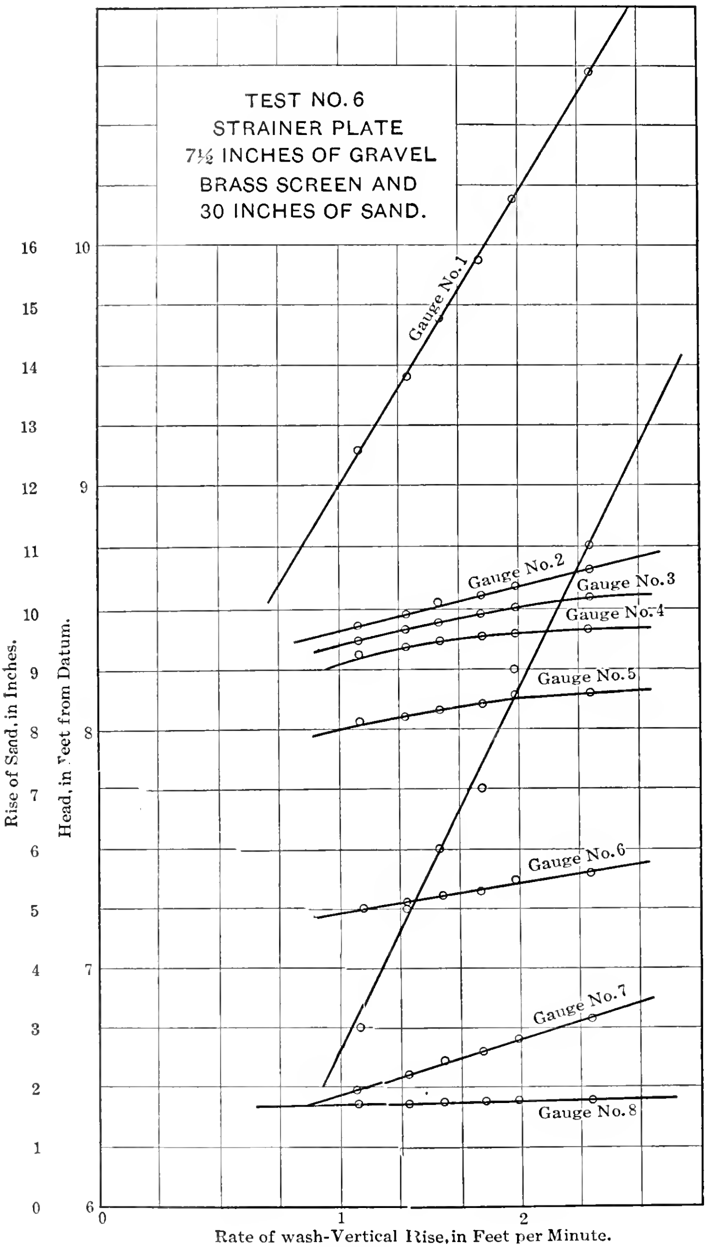

TEST NO. 6
STRAINER PLATE
7½ INCHES OF GRAVEL
BRASS SCREEN AND
30 INCHES OF SAND.
Gauge No. 1
Gauge No. 2
Gauge No. 3
Gauge No. 4
Gauge No. 5
Gauge No. 6
Gauge No. 7
Gauge No. 8
Rise of Sand, in Inches.
Head, in Feet from Datum.
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
6 7 8 9 10
0 1 2
Rate of wash-Vertical Rise, in Feet per Minute.

FIG. 9.

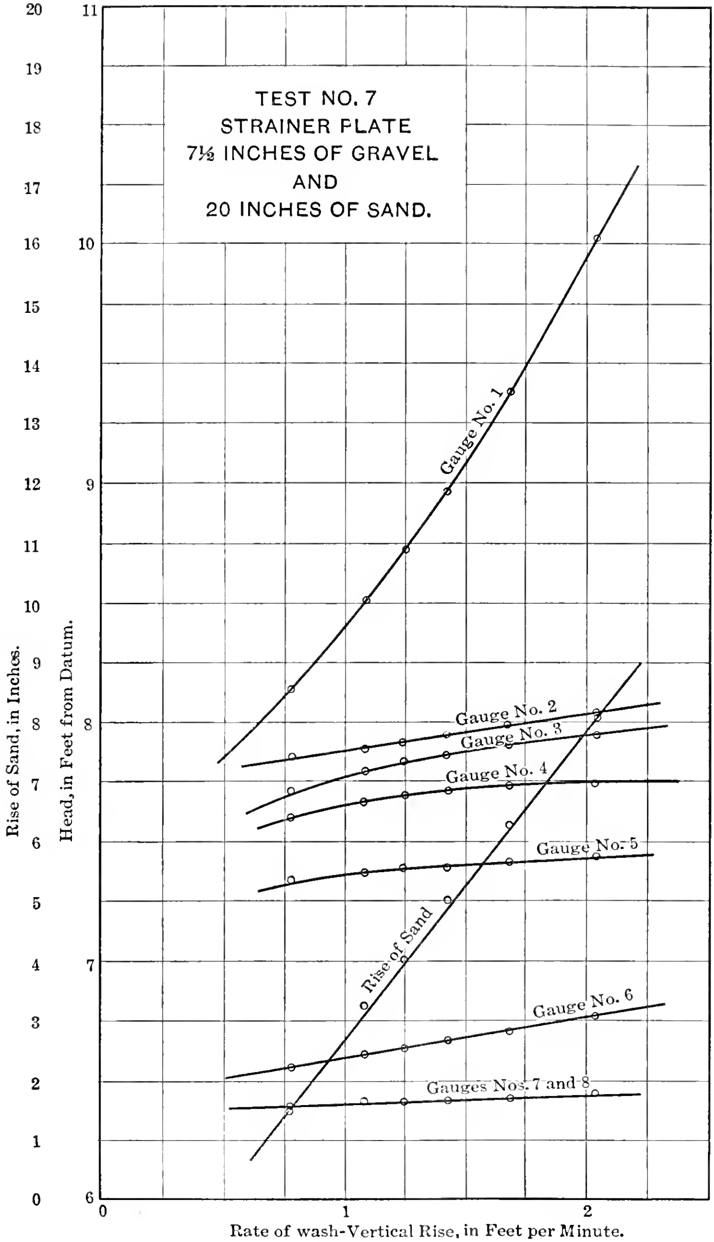

TEST NO. 7
STRAINER PLATE
7½ INCHES OF GRAVEL
AND
20 INCHES OF SAND.
Gauge No. 1
Gauge No. 2
Gauge No. 3
Gauge No. 4
Gauge No. 5
Rise of Sand
Gauge No. 6
Gauges Nos. 7 and 8
Rise of Sand, in Inches.
Head, in Feet from Datum.
Rate of wash-Vertical Rise, in Feet per Minute.
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

FIG. 10.

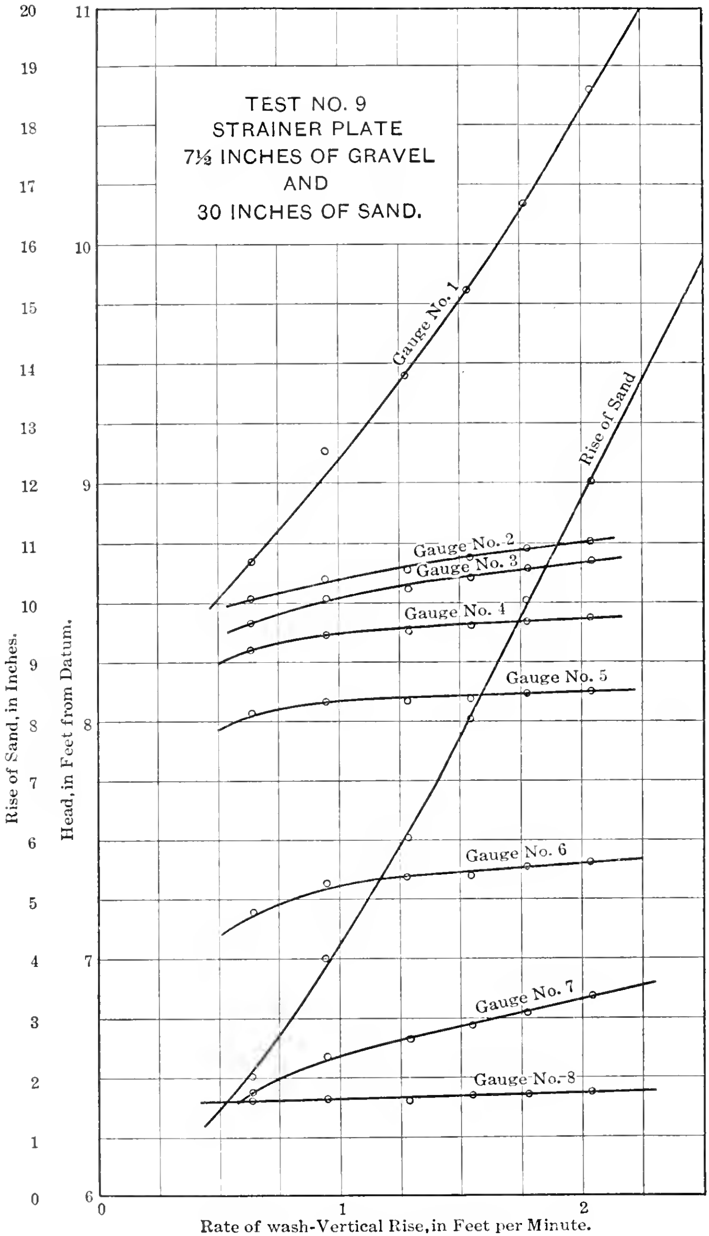

TEST NO. 9
STRAINER PLATE
7½ INCHES OF GRAVEL
AND
30 INCHES OF SAND.
Gauge No. 1
Rise of Sand
Gauge No. 2
Gauge No. 3
Gauge No. 4
Gauge No. 5
Gauge No. 6
Gauge No. 7
Gauge No. 8
Rise of Sand, in Inches.
Head, in Feet from Datum.
Rate of wash-Vertical Rise, in Feet per Minute.

FIG. 11.

surface of the floating sand just reached the outlet to Gauge No. 7, and thus affected the reading.

In all the tests, with both sand and gravel in the filter, and without the separating brass wire screen, the gravel could not be made to

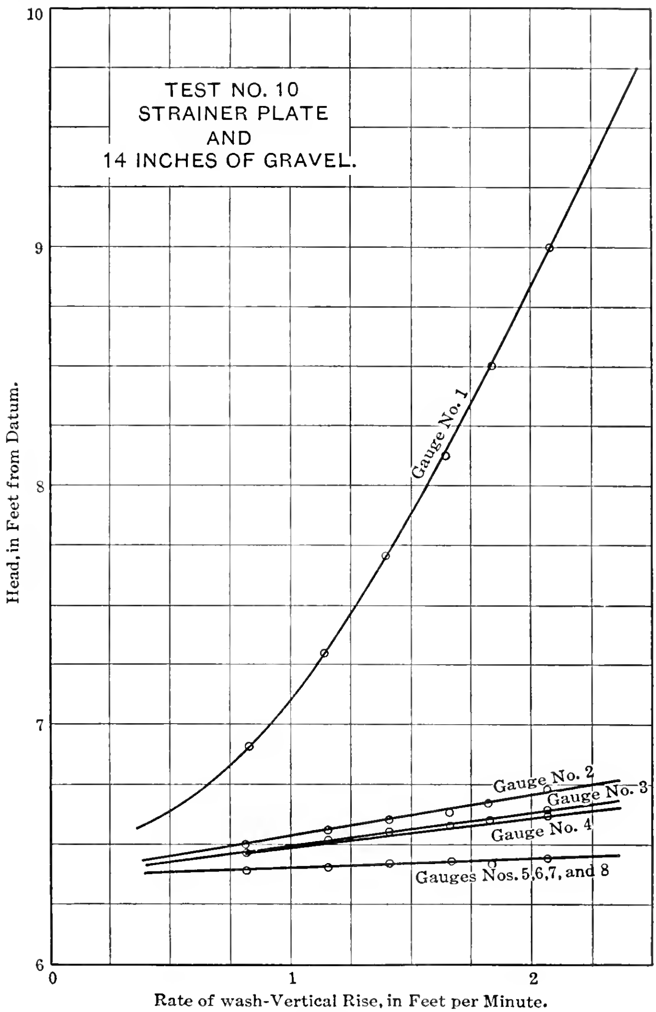


FIG. 12.

mix with the sand with an upward velocity of the wash-water as high as 2 ft. per min. It was not even apparently disturbed by suddenly applying the wash-water to the drained filter bed at a rate of 2 ft.

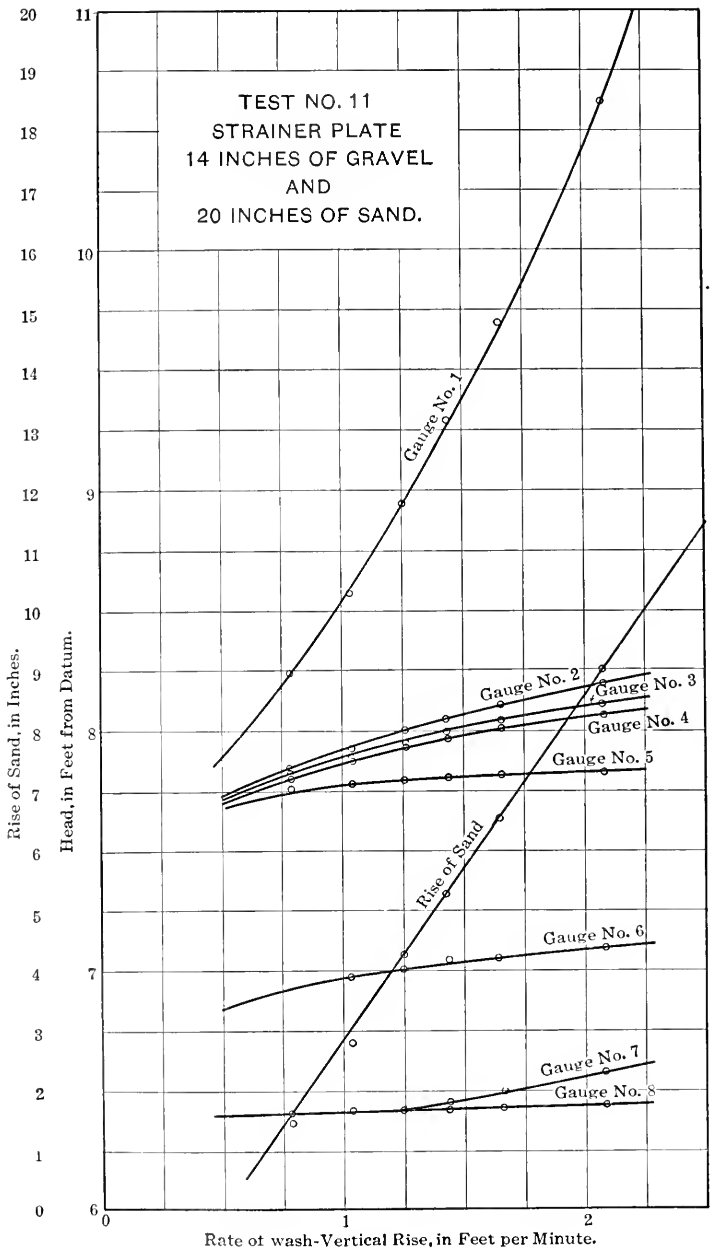

TEST NO. 11
STRAINER PLATE
14 INCHES OF GRAVEL
AND
20 INCHES OF SAND.
Gauge No. 1
Gauge No. 2
Gauge No. 3
Gauge No. 4
Gauge No. 5
Gauge No. 6
Gauge No. 7
Gauge No. 8
Rise of Sand
Rise of Sand, in Inches.
Head, in Feet from Datum.
Rate of wash-Vertical Rise, in Feet per Minute.

FIG. 13.

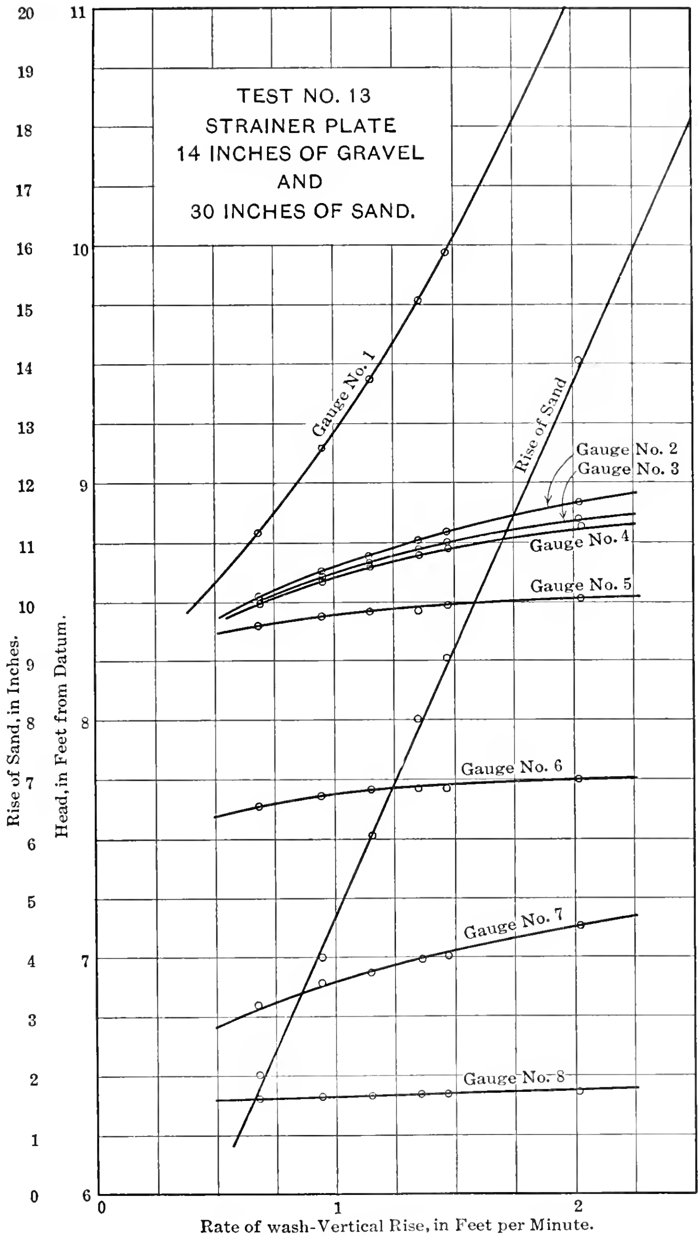

TEST NO. 13
STRAINER PLATE
14 INCHES OF GRAVEL
AND
30 INCHES OF SAND.
Gauge No. 1
Rise of Sand
Gauge No. 2
Gauge No. 3
Gauge No. 4
Gauge No. 5
Gauge No. 6
Gauge No. 7
Gauge No. 8
Rise of Sand, in Inches.
Head, in Feet from Datum.
20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
11 10 9 8 7 6
0 1 2
Rate of wash-Vertical Rise, in Feet per Minute.

FIG. 14.

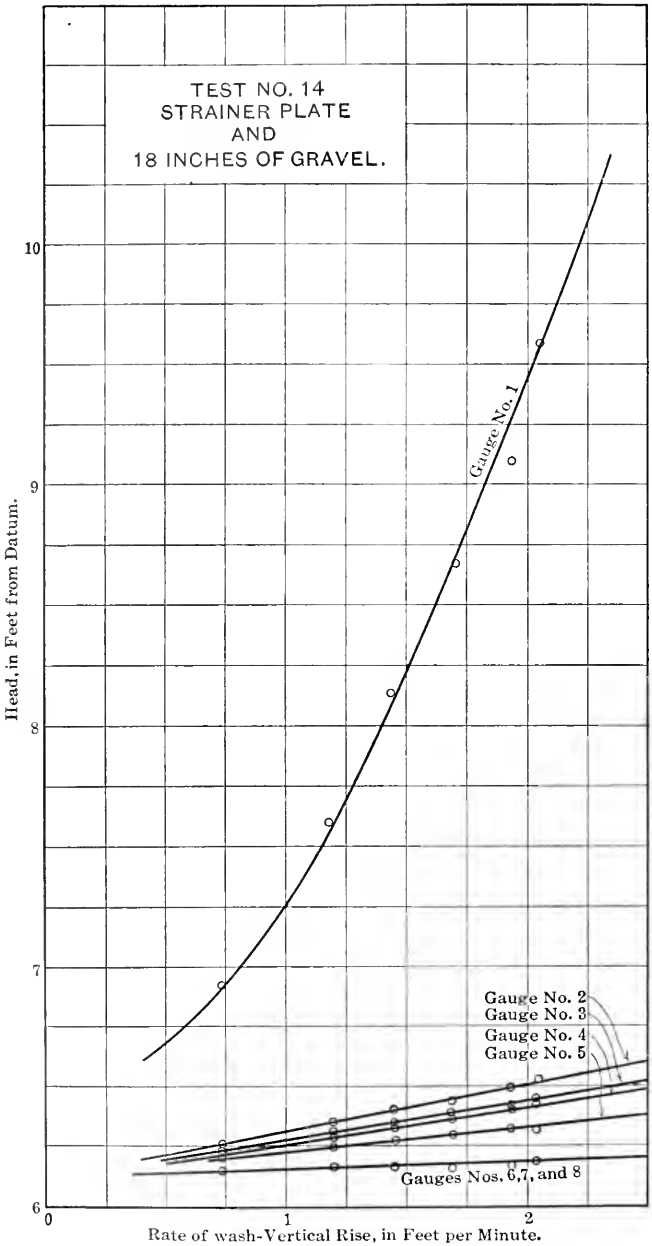
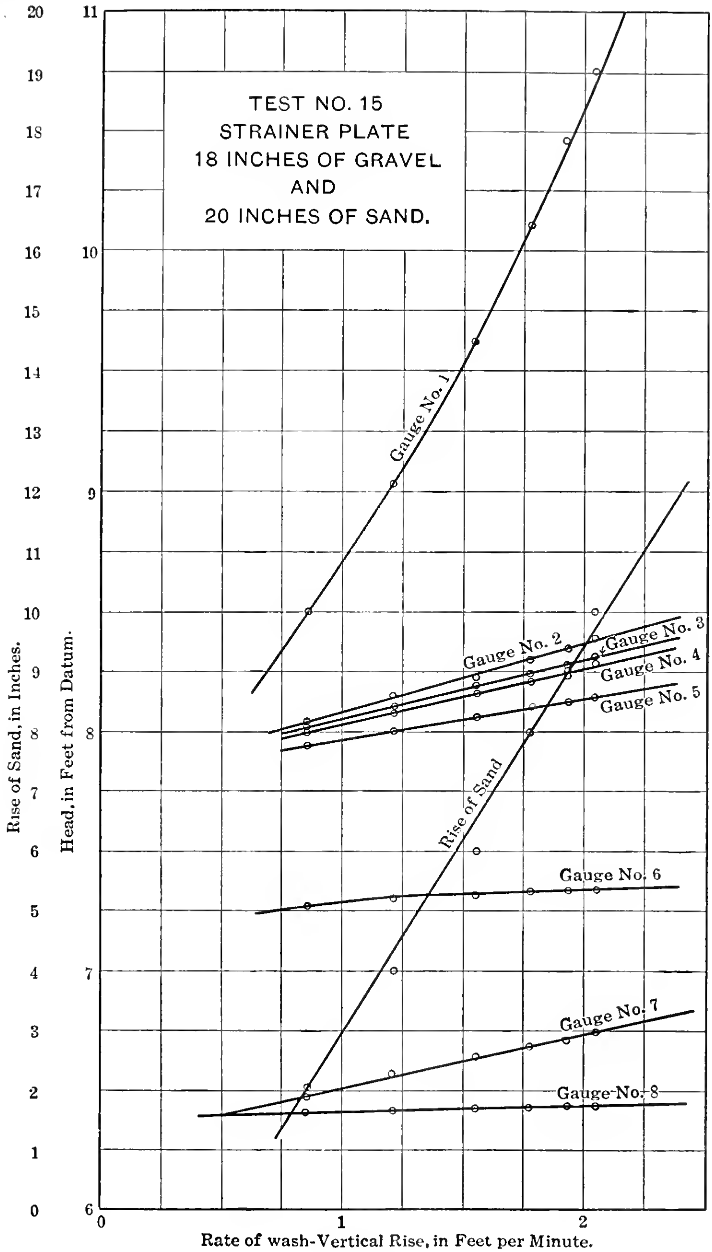

TEST NO. 14
STRAINER PLATE
AND
18 INCHES OF GRAVEL.
Gauge No. 1
Gauge No. 2
Gauge No. 3
Gauge No. 4
Gauge No. 5
Gauges Nos. 6,7, and 8
Head, in Feet from Datum.
10
9
8
7
6
0
1
2
Rate of wash-Vertical Rise, in Feet per Minute.

FIG. 15.



TEST NO. 15
STRAINER PLATE
18 INCHES OF GRAVEL
AND
20 INCHES OF SAND.
Gauge No. 1
Gauge No. 2
Gauge No. 3
Gauge No. 4
Gauge No. 5
Gauge No. 6
Gauge No. 7
Gauge No. 8
Rise of Sand
Rise of Sand, in Inches.
Head, in Feet from Datum.
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
11
10
9
8
7
6
0
1
2
Rate of wash-Vertical Rise, in Feet per Minute.

FIG. 16.

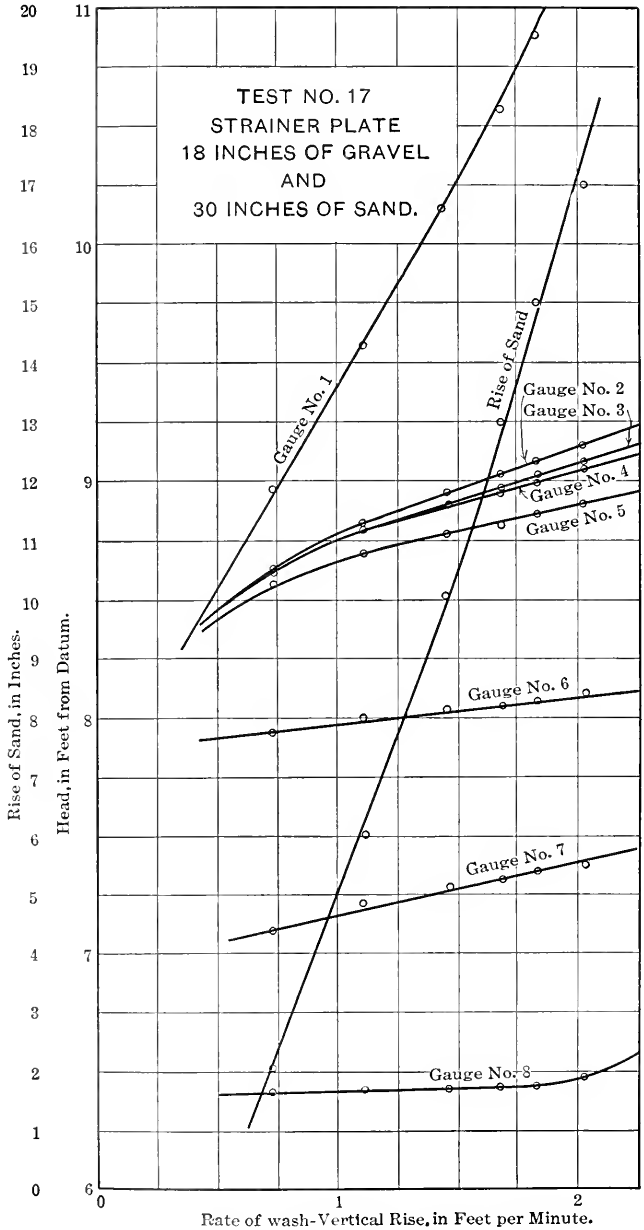

TEST NO. 17
STRAINER PLATE
18 INCHES OF GRAVEL
AND
30 INCHES OF SAND.
Gauge No. 1
Rise of Sand
Gauge No. 2
Gauge No. 3
Gauge No. 4
Gauge No. 5
Gauge No. 6
Gauge No. 7
Gauge No. 8
Rise of Sand, in Inches.
Head, in Feet from Datum.
Rate of wash-Vertical Rise, in Feet per Minute.
0
1
2
6
7
8
9
10
11
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

FIG. 17.

per min., so that the rising wash-water would be mixed with the air trapped under the strainer system and in the gravel and sand of the filter bed. These conditions are the most severe to which filter sand and gravel can be subjected in practice, as the escape of the air and water together lifts the sand bed bodily at first, followed almost immediately by explosive discharges of air and water at points of least resistance on the surface of the sand. When the filter was drained, by allowing the water to pass downward through the sand and gravel and flow out through the 4-in. discharge pipe under the strainer system, observations through the glass windows showed that the sand was not carried downward into the gravel. It is obvious that, if the mixing of the sand and gravel is to be prevented, the latter must be graded properly from the bottom layer to the sand line.

In order to compare the losses of head through the various portions of the filter under different conditions, Table 2 has been arranged with data taken from the curve sheets. This table was compiled from all the tests in which sand was used in the filter, and the data are tabulated for upward velocities of the wash-water of 1.0, 1.5, and 2.0 ft. per min. The column, "Loss of Head Through Filter", was obtained by taking the difference between the height of the water flowing over the gutters and the reading of Gauge No. 1. The column, "Loss of Head Through Strainer Plates", was obtained by taking the difference between Gauges Nos. 1 and 2 in the various experiments when the sand and gravel were in place. These figures for the loss of head through the strainer plates differ from those obtained when there was no gravel over the strainers. The gravel closes some of the openings in the strainer plates, and thereby causes an increase in the loss of head through them for the same upward velocity of the wash-water.

The loss of head through the gravel was obtained from the difference in readings between Gauge No. 2 and some gauge above the gravel layer. These readings for the loss of head through the gravel were taken from the tests made before the sand was placed over the gravel. The column, "Loss of Head Through Sand", was obtained by taking the difference between the "Loss of Head Through Filter" and the sum of the losses of head through the strainer plates and gravel. These results have been plotted in the form of curves on Fig. 18.

TABLE 2.—DATA FROM CURVE SHEETS.

Test No.	Depth of gravel, in inches.	Depth of sand, in inches.	Upward velocity of wash-water, in feet per minute.	Total head applied under filter.	Static head.	LOSS OF HEAD, IN FEET OF WATER.				Rise of sand, in inches.
						Through filter.	Through strainer plates.	Through gravel.	Through sand.	
4*	7½	20	1.0	8.33	6.40	1.93	0.58	0.06	1.29	2.5
4*	7½	20	1.5	9.00	6.42	2.58	1.20	0.09	1.29	4.9
4*	7½	20	2.0	9.92	6.43	3.49	2.05	0.14	1.30	7.3
5*	7½	25	1.0	8.70	6.40	2.30	0.60	0.06	1.64	2.8
5*	7½	25	1.5	9.42	6.42	3.00	1.22	0.09	1.69	6.3
5*	7½	25	2.0	10.29	6.43	3.86	2.03	0.14	1.69	9.8
6*	7½	30	1.0	9.00	6.40	2.60	0.60	0.06	1.94	2.6
6*	7½	30	1.5	9.81	6.42	3.39	1.30	0.09	2.00	6.6
6*	7½	30	2.0	10.63	6.43	4.20	1.99	0.14	2.07	10.7
7	7½	20	1.0	8.40	6.40	2.00	0.50	0.06	1.44	2.7
7	7½	20	1.5	9.07	6.42	2.65	1.12	0.09	1.44	5.3
7	7½	20	2.0	9.93	6.43	3.50	1.90	0.14	1.46	7.9
8	7½	25	1.0	8.75	6.40	2.35	0.50	0.06	1.79	3.7
8	7½	25	1.5	9.42	6.42	3.00	1.10	0.09	1.81	6.8
8	7½	25	2.0	10.27	6.43	3.84	1.90	0.14	1.80	9.8
9	7½	30	1.0	9.10	6.40	2.70	0.50	0.06	2.14	4.2
9	7½	30	1.5	9.76	6.42	3.34	1.07	0.09	2.18	7.8
9	7½	30	2.0	10.57	6.43	4.14	1.80	0.14	2.20	11.8
11	14	20	1.0	8.54	6.40	2.14	0.60	0.13	1.41	2.9
11	14	20	1.5	9.38	6.42	2.96	1.32	0.20	1.44	5.7
11	14	20	2.0	10.41	6.43	3.98	2.22	0.28	1.48	8.5
12	14	25	1.0	8.80	6.40	2.40	0.60	0.13	1.67	3.7
12	14	25	1.5	9.70	6.42	3.28	1.27	0.20	1.81	7.5
12	14	25	2.0	10.75	6.43	4.32	2.20	0.28	1.84	11.4
13	14	30	1.0	9.22	6.40	2.82	0.57	0.13	2.12	4.7
13	14	30	1.5	10.03	6.42	3.61	1.22	0.20	2.19	9.2
13	14	30	2.0	11.10	6.43	4.67	2.20	0.28	2.19	13.7
15	18	20	1.0	8.70	6.40	2.30	0.62	0.15	1.53	3.0
15	18	20	1.5	9.53	6.42	3.11	1.32	0.22	1.57	6.2
15	18	20	2.0	10.58	6.43	4.15	2.23	0.32	1.60	9.4
16	18	25	1.0	9.02	6.40	2.62	0.64	0.15	1.83	4.1
16	18	25	1.5	9.87	6.42	3.45	1.33	0.22	1.90	7.7
16	18	25	2.0	10.92	6.43	4.49	2.20	0.32	1.97	11.3
17	18	30	1.0	9.40	6.40	3.00	0.62	0.15	2.23	4.9
17	18	30	1.5	10.25	6.42	3.83	1.30	0.22	2.31	10.2
17	18	30	2.0	11.22	6.43	4.79	2.10	0.32	2.37	15.6†

* Brass wire screen in place.

† Fine sand passed over wash-water troughs.

The curves for the loss of head through the strainer plates, through the gravel, and through 20, 25, and 30 in. of sand for the same depth of material, are the averages for the losses recorded in Table 2. The curves for the loss of head through the entire filter are not averages, but represent the curves for the individual tests. The curves for the loss of head through the entire filter, when using 7½ in. of gravel, and 25 and 30 in. of sand, were omitted on this curve sheet, as they crossed other curves and confused the lines.

It is seen from these curves that the loss of head through the gravel was a very small part of the total loss of head through the

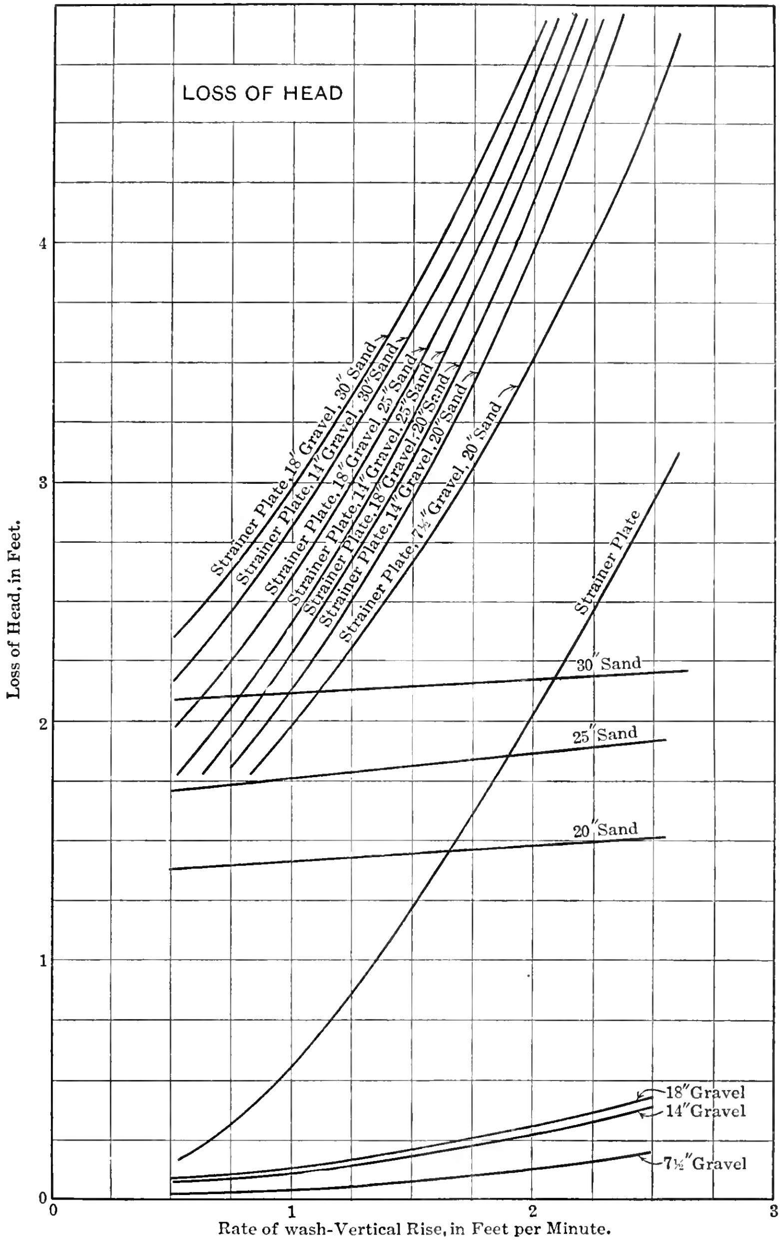

LOSS OF HEAD
Strainer Plate, 18" Gravel, 30" Sand
Strainer Plate, 14" Gravel, 30" Sand
Strainer Plate, 18" Gravel, 25" Sand
Strainer Plate, 14" Gravel, 25" Sand
Strainer Plate, 18" Gravel, 20" Sand
Strainer Plate, 14" Gravel, 20" Sand
Strainer Plate, 7½" Gravel, 20" Sand
Strainer Plate
30" Sand
25" Sand
20" Sand
18" Gravel
14" Gravel
7½" Gravel
Loss of Head, in Feet.
Rate of wash-Vertical Rise, in Feet per Minute.
0
1
2
3
4

FIG. 18.

filter. With an upward velocity of the wash-water of 2 ft. per min., the loss of head through the strainer plate was 2 ft.; through the 30 in. of sand, the loss of head was 2.2 ft., when washing at a rate of 2.0 ft. per min. From a study of these curves, it is interesting to note the effect on the loss of head through the sand of changes in the upward velocity of the wash-water. The loss of head through the sand increased very slowly as the upward velocity of the wash-water increased. The wash-water pushed the sand grains farther apart as the velocity increased, and more water flowed through the sand bed, but with very little increase in the loss of head through the sand.

Fig. 19 has four curves, three of which are from experiments in which the sand had an effective size of 0.41 mm. The other curve is taken from another set of experiments in which was used a 30-in. depth of sand which had an effective size of 0.31 mm. (Fig. 20 shows the mechanical analysis of this sand.) These curves represent the average of the distances obtained in the various tests between the top of the floating sand during the process of washing and the normal level of the sand when compacted during the process of draining. They also show that the height of flotation of sand having the same effective size, and subjected to the same upward velocity of the wash-water, was proportional to the depth of the sand. An analysis of the coarser sand used in these experiments is shown by Fig. 3.

When using the finer grade of sand in the filter, the height to which the sand floated was greater than that obtained with the coarser sand. This is shown by the curve for the rise of the sand with an effective size of 0.31 mm. With an upward velocity of the wash-water of 2 ft. per min., this difference amounted to 4½ in. On a number of tests with the large 4 000 000-gal. filter units at the Cincinnati Filtration Plant, a rise of 20 in. of the sand was obtained with an upward velocity of the wash-water of 2 ft. per min. The sand in these filters has an effective size of 0.39 mm., and a uniformity coefficient of 1.35. The measurement of the rise of the sand in the large filter units was made during the regular process of washing, after the filter had been removed from service on account of the accumulation of sediment in the sand bed. In this case the sand was dirty, whereas, in the set of experiments with the experimental filter, the sand was clean, due to the fact that it was continuously subjected to the washing process with filtered water, and was not used to filter water containing sediment.

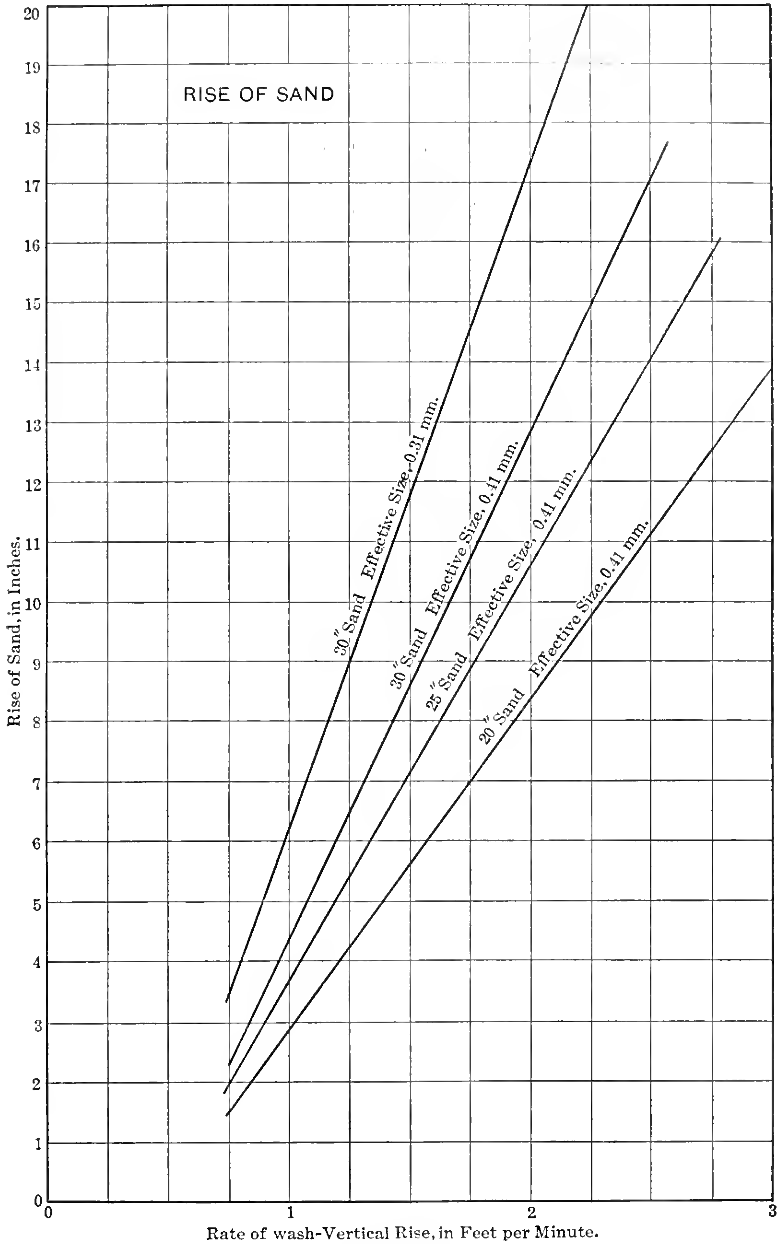

RISE OF SAND
30" Sand Effective Size, 0.31 mm.
30" Sand Effective Size, 0.41 mm.
25" Sand Effective Size, 0.41 mm.
20" Sand Effective Size, 0.41 mm.
Rise of Sand, in Inches.
Rate of wash-Vertical Rise, in Feet per Minute.
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
0
1
2
3

FIG. 19.

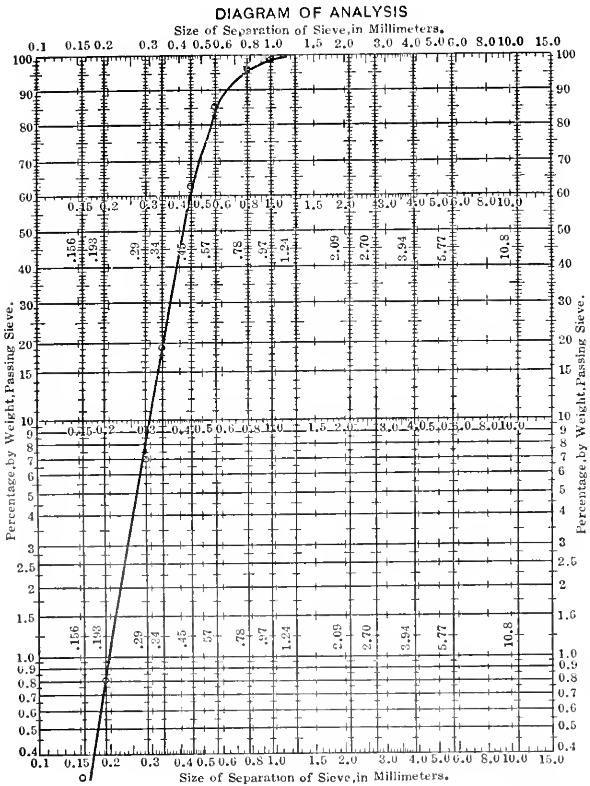


FIG. 20.

CINCINNATI, OHIO

MECHANICAL ANALYSIS OF FILTERING MATERIAL

No. of Sample EXPERIMENTAL FILTER

Location of Deposit AVERAGE OF 30" DEPTH (ALL)

Date of Collection MAY 16, 1913

Date of Analysis MAY 16, 1913

Remarks

Size of Separation of Sieve		Weight Passing Sieve, in Grammes	Percentage, by Weight, Passing Sieve
No.	Mm.		
2	10.8		
4	5.77		
6	3.94		
8	2.70		
10	2.09		
16	1.24		
20	0.97	98.0	98.0
24	0.78	95.3	95.3
30	0.57	85.6	85.6
40	0.45	62.3	62.3
50	0.34	19.5	19.5
60	0.29	7.0	7.0
80	0.193	.8	.8
100	0.156	.3	.3

Amount examined 100 *Grammes*

Effective Size 10 per cent finer than 0.31 *mm.*

60 per cent finer than 0.45 *mm.*

Uniformity Coefficient 1.45

Per cent finer than 0.20 mm. =

" " " " 0.25 mm. =

" " " " 0.85 mm. =

Observations on the Original and on Two Reconstructed Filter Units of the Cincinnati Filter Plant.

The large filter units are 50 ft. long, and each half of the unit is 14 ft. wide. The wash-water gutters (Fig. 6) are 14 ft. long and 18 in. wide, and run the width of the filter. There are six of these gutters in each half of the filter unit, and the area covered by them is 18% of the sand area of the filter. The upward velocity of the wash-water is computed from the volume of water used per minute and the sand area (1 400 sq. ft.) of the filter. During the washing process, when the sand rises between the parallel sides of the gutters it reaches a body of water which is moving upward with a greater velocity than that below the gutters, on account of the decreased sectional area. Taking this fact into consideration, and correcting for the change in the upward velocity of the wash-water between the gutters, the measurements made on the large filter units for the rise of sand agree more nearly with the results obtained in the experimental filter.

The large filter unit (No. 19), from which the screen had been removed on one side and with which experiments had been attempted, was examined carefully in order to find what caused the side without the screen to wash so poorly and the water to drain out so slowly. The trouble was found in the strainer plates. In replacing these plates, workmen had used a cloth in some places to wipe off the cement from the top of the plates. This had forced some of the wet cement into the small openings of the strainer plates, where it had hardened and thus plugged them up. After cleaning out the holes in the plates, both sides of this filter were rebuilt without using the brass screen, 14 in. of gravel being used and placed as recorded in Test No. 10.

The original sand was placed on top of the gravel, which gave a depth of 30 in. to the sand layer. When the filter was washed with water having an upward velocity of 2 ft. per min., the sand flowed over the edges of the gutters. In order to prevent the loss of sand, the maximum upward velocity of the wash-water was reduced to 1.5 ft. per min., when estimated on the basis of the sand area. Fig. 6 shows the heights to which the main body of the sand floated in the 4 000 000-gal. filter units with upward velocities of the wash-water of 1.5 and 2 ft. per min.

Loss of sand over the edges of the gutters took place in the large filter units when the main body of the sand floated farther below the

WASH-WATER GUTTERS OF THE CINCINNATI FILTER PLANT.

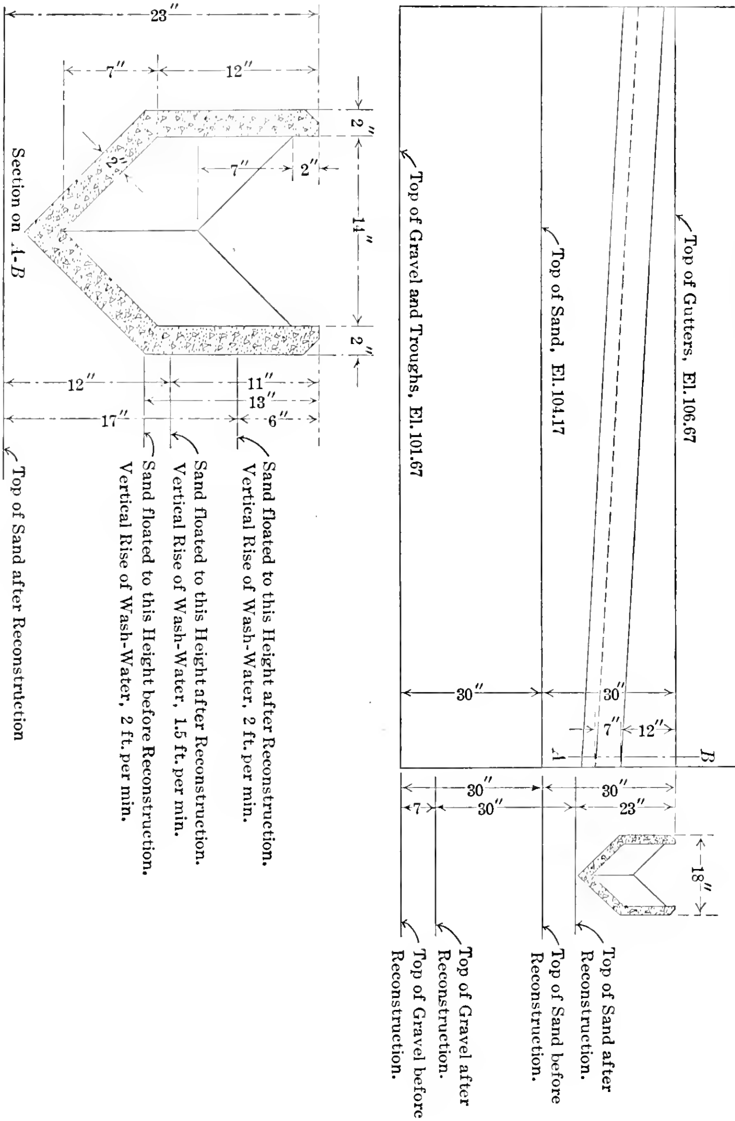
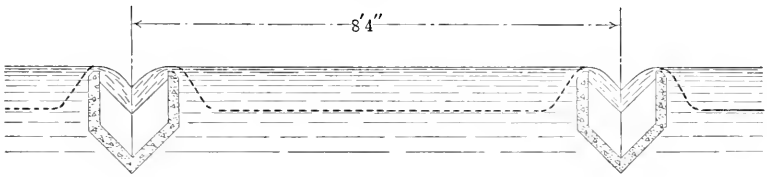


Fig. 21.

gutter edges than it did in the experimental filter. The reason for this is discussed in a subsequent paragraph.

The distance between the edges of the two gutters in the experimental filter was only 2 ft., but, in the large filter units of the plant, this distance is 6 ft. 10 in. The velocity of the water in the latter case is greater in the vicinity of the gutters than when the latter are closer together. The effect of the increased velocity of the wash-water in the vicinity of the gutters is to carry the sand over with the water. The difference in velocity is shown clearly during the process of washing a filter. The muddy water rising from the sand during the first part of the wash, and which is nearest to the gutters, commences to pass over into them when the upper surface of the main body of the rising sediment has still 8 or 10 in. to travel before reaching the surface of the water. Fig. 22 represents the effect of the increased velocity of the water in the vicinity of the gutters.

RISE OF SEDIMENT DURING PROCESS OF WASHING.



The dotted line represents the surface of the muddy water rising from the sand during the first part of the wash. The muddy water nearest the gutters is just passing over, and the greater part of the rising sediment between the two gutters has from 8 to 10 in. more to rise before reaching the surface.

Fig. 22.

Another factor, which has an influence on the sand being carried over into the gutters in the large filters when it reaches a certain height, is the shape of the sides of the gutters. From Figs. 6 and 7 it will be seen that the gutters used in the large filter units are pointed at the bottom, and that they have perpendicular sides, whereas the sides of the gutters in the experimental filter sloped at an angle of 45 degrees. During Test No. 17 with the experimental filter, some of the sand passed over the gutters and the main body of the sand remained about 0.5 ft. below their tops. It could be seen that the sand which floated into the gutters came from the main body of the sand immediately below their outer edges, and through the zone of highest velocity of the wash-water. The material which escaped was only the finest sand particles, or silt.

Filter No. 5 was rebuilt, using 7½ in. of gravel and 30 in. of sand, but without the brass wire screen. The 7½ in. of gravel were placed as recorded in Test No. 2. Both filters—Nos. 5 and 19—have been in service for more than a year. From time to time, holes have been dug at various places in both these filters, and they have been examined carefully to see whether the sand was working its way down into the gravel. Thus far, they have been found to be in perfect condition, and their behavior in operation has been entirely satisfactory.

Conclusions Reached Relative to Reconstruction of All Filter Beds in Cincinnati Filter Plant.

The gravel in a rapid sand filter has three functions: It supports the sand layer; acts as a distributor of the rising wash-water, thereby making the upward pressure more uniform under the sand layer; and prevents the sand from passing downward to the strainer plates and clogging their openings. If these are the conditions which must be met, the practical questions to be decided relate to the total depth and the proper sizes of the stones forming the gravel layer.

The data collected during these experiments appeared to the writers to be sufficient to answer these questions, and, in consequence, the reconstruction of all the filter beds has been undertaken.

The 7½ in. of gravel used in the tests and in Filter No. 5 had proved successful, as also had the 14 in. of gravel used in Filter No. 19. Gravel, as it is pumped and screened on barges in the Ohio River near Cincinnati, contains all the material that will pass through a 2-in. hole.

Starting with gravel having an approximate diameter of 2 in., it would be possible to build an effective gravel bed with a depth of only 5 in. In the large filter units, it is necessary for the men who are placing the gravel to walk on it while they spread it out with rakes. It was decided, therefore, to build the gravel bed so deep that there would be no trouble due to the mixing of the different layers of gravel by the men walking on it, and the 14 in. of gravel used in Test No. 10 was decided on as giving a sufficient factor of safety in this respect.

In any gravel layer, acting as a support for the sand of a filter, there must be, of course, a rather uniform gradation from the coarsest to the finest particles, in order that the penetration of the smaller stones of the layer of gravel above into the voids at and near the surface of the layer below shall not be too great. This fact was taken into consideration in selecting the screens used for separating the various sizes of gravel desired. Consideration was also given to the various sizes of gravel which could be obtained by screening washed Ohio River gravel as it was commonly sold, so that as little waste of material as possible should result.

The sand layer placed on the 4-in. gravel layer which had passed a ¼-in. mesh screen is washed in the filter in the usual way. This produces a gradation of its particles which merges them into the gravel layer beneath and thus forms a uniformly graded whole, commencing at the strainer plate with the 2-in. stones and ending with the finest sand at the surface of the bed.

The estimated cost of renewing the brass wire screen and of placing the filters of the Cincinnati Filter Plant in the same condition as that in which they were originally, was more than $15 000. To have improved on the imperfect method of fastening the screen would have probably cost from $5 000 to $10 000 additional, or a total of from $20 000 to $25 000, depending on the improved method adopted.

From carefully kept cost records of the various operations required in rebuilding the filter beds, and including the cost of extra gravel, which is obtained for $1.39 per ton, the average cost for reconstructing each filter bed is $280. This makes the total cost of rebuilding the beds $7 854, to which should be added $650 for half the time of a foreman in supervising the work. The total cost, therefore, will be approximately $8 500, as compared with $20 000 or $25 000 for a renewal of the brass wire screen and improved methods of fastening it. As corrosion of the screen was inevitable, and as, by the substitution of a deeper gravel bed for the screen, the elimination of the latter was found to be possible, it seems that the problem has been satisfactorily solved.

Conclusions.

The conclusions reached as a result of the experimental work and of the writers' observations of the large filters of the Cincinnati plant may be briefly summarized as follows:

1.—In washing a rapid sand or mechanical filter, at rates of from 1.0 to 2.0 ft. vertical rise of the wash-water per minute, the greatest losses of head occur in the strainer system and in the sand.

2.—The loss of head through the strainer system used (which had openings equal to 0.3% of the sand area of the filter) was never greater than 2.22 ft., even with a velocity of the wash-water of 2.0 ft. per min.

With other forms of strainer systems and with different areas of openings the losses of head would differ, of course, from those found, even with the same velocities of wash-water.

3.—The loss of head in the gravel layer was found to be less than ⅓ ft. even with a velocity of the wash-water of 2.0 ft. per min. and with a gravel layer 18 in. deep.

4.—The loss of head through the sand did not exceed 2.37 ft. with a depth of 30 in. of sand and with a rate of flow of the wash-water of 2.0 ft. vertical rise per minute.

5.—The height of flotation of the sand during the washing process is affected by the depth of the sand, by its fineness, and by the velocity and uniformity of distribution of the wash-water. It is proportional apparently to the depth of the sand bed, other conditions being equal. Loss of sand over the edges of the waste troughs, during the washing process in the Cincinnati filters, was found to be influenced by the increased velocity of the wash-water, produced by the submergence of the gutters in the rising wash-water and by the distance of the floating sand from the bottom and sides of the gutters. Submergence of the gutters in the floating sand is undesirable.

6.—It was found that a properly graded layer of gravel would act as a distributor of the rising wash-water; and that layers as deep as 18 in. produced very low losses of head. Gravel layers 14 in. deep, and graded carefully in size from stones 2 in. in diameter at the bottom to particles that had passed through a ¼-in. mesh sieve at the top, were adopted as affording a sufficient margin of safety against improper grading in placing, or disturbance by wash-water moving at high velocity through the gravel.

7.—It was found possible, by introducing the deeper gravel layers in the Cincinnati filters, to do away with the brass wire screen originally placed between the gravel and sand, and which, although it provided at first a positive method of preventing the gravel and sand layers from becoming mixed, developed in the course of two or three years a mechanical weakness, due to imperfect methods of fastening and to disintegration of the brass itself by corrosion, thereby making it useless.

8.—The cost of renewal and of improving the method of fastening the brass wire screen in the Cincinnati filters was estimated to be nearly two and one-half to three times the cost of rebuilding the filters with deeper gravel beds, and the latter method, therefore, was adopted.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

THE EFFECTS OF STRAINING STRUCTURAL STEEL AND WROUGHT IRON

By Henry S. Prichard, M. Am. Soc. C. E.

To be Presented March 1st, 1916.

Synopsis.

Iron, in combination and mixture with small proportions of carbon and other substances, and variously treated in its manufacture, is produced for commercial purposes in many varieties, which differ greatly in strength and ductility but little as regards the rate at which, within the elastic limit, dimensions and bulk are changed by straining at ordinary atmospheric temperatures. One variety, made by welding plastic masses which contain very little carbon and some slag, is termed wrought iron. This is a ductile variety, comparatively low in strength. Most of the other varieties are known as steel. One now little used variety of steel, slag-bearing or weld steel, is made from wrought iron by heating and adding carbon, but without remelting. The other varieties of steel are slagless and, when not simply cast, are made from steel castings (termed ingots) by mechanical and thermal treatment. The different varieties of steel cover a large range of strength, ductility, and hardness, the comparatively soft varieties being more ductile than wrought iron, and the very softest being slightly weaker.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

The changes in dimensions and shape which take place in pieces of steel or wrought iron when they are strained are brought about either in the first of two certain ways, or in both of these ways in conjunction, depending on the severity of the straining. When strained in the first way, the changes in dimensions, shape, and bulk of a strained piece are effected entirely by changes in dimensions, shapes, and bulks of the particles of the piece, without any sensible slipping of one particle over another. A piece thus strained, on the cessation of the forces which caused the straining, returns to its original size and shape in every part and in every particular; hence the piece is not over-strained and, within the limits of straining within which its each and every part acts in this way, is perfectly elastic. The second way in which changes are effected is by the sliding of particles one over the other under shearing forces, whether the forces are simple shears or the shearing components of tension or compression. Such sliding is caused by straining the metal beyond its capacity to resist shear, and such straining is called over-straining. The changes in dimension and shape resulting therefrom are permanent; but the sliding particles, excepting metal between the sliding surfaces, remain elastic within themselves, and return to their former dimensions and shapes, though in new positions and with changed inclinations, on the cessation of the forces which strained them; hence an over-strained piece is still partly elastic, and tends, to that extent, to recover its original dimensions and shape on the cessation of straining forces.

The elastic limit of steel and wrought iron, though expressed in cases of direct stress with respect to said stress, is determined by the limit to shearing resistance, and is the same in tension and compression, for the reason that the shearing components are the same.

In ordinary testing of structual steel and wrought iron, in tension or compression, the first indication that the elastic limit has been exceeded is usually a breaking of the mill scale, when there is any, followed by a sudden and pronounced yielding. The point at which the pronounced yielding occurs is known as the yield point. When micrometers are used to measure the elongations or compressions, a readily appreciable but lesser yielding can usually, but not always, be observed prior to and within a few thousand pounds per square inch of the yield point. Graphically represented, this preliminary yielding is, roughly, in the form of a curve tangent to the line representing elastic elongation or compression. The beginning of this preliminary yielding is termed the "proportional elastic limit", or simply the "elastic limit", which is the older, more familiar, and better designation.

When measurements are made with great precision on long gauged lengths, slight imperfections in elasticity, due to initial internal stresses developed during and by the processes of manufacture, can usually be detected at stress intensities far below the point known as the elastic limit in pieces of steel or wrought iron strained for the first time; but, in pieces subjected to only one kind of stress, these imperfections are not important, as the permanent sets in such pieces are very small and the elasticity can be perfected to the elastic limit by straining to that limit. In pieces subjected to alternate direct tension and compression, the elasticity can similarly be perfected; but, if the alternations are rapid and continuous, it cannot be perfected to as high a limit.

When a piece of steel or wrought iron is over-strained, the metal between the surfaces of the sliding particles is viscous, during the over-straining action, in the popular sense of being sticky; that is, it adheres to the adjoining solid particles and has great tensional resistance, and—in the scientific sense of flowing under force but offering resistance as regards the velocity of flow—the flow increases with the intensity of the force and decreases with the degree of viscosity, being very slow when the viscosity is very great. The viscous metal, like the substance pitch, is a liquid, judged by its properties, but, like pitch, is solid in its appearance. The energy which makes and keeps the metal liquid is not in this case applied as heat, but as mechanical force.

Any film of steel or wrought iron made viscous by over-straining at an ordinary atmospheric temperature is at a temperature far below its normal freezing point, and, when released from the shear which makes it viscous, resolidifies with great rapidity. There is considerable evidence to show that after the film has resolidified it is amorphous, like glass, and not crystalline in its structure, and experiments lead to the conclusion that in its supposed amorphous condition it is much stronger than in the original crystalline state in which the solidification had been gradual.

Over-strained steel or wrought-iron pieces suffer temporary loss of strength while the viscous metal is resolidifying; but, as the viscous metal resolidifies with great rapidity on the release of stress, an over-strained piece regains most of its elasticity within a few minutes after the removal of the external forces. If, however, the straining has been much above the yield point, the elastic solid portion of the metal in its recoil will act on the viscous portion and prevent complete solidification for hours or even days and weeks.

When steel or wrought iron is ruinously over-strained, the solid particles will tear apart instead of simply sliding one over the other, and will have to be reheated, or, in severe cases, entirely remelted, before they can again be united. Small tears, not in themselves discernible, will be extended by long-continued or oft-repeated stresses until they cause rupture. This phenomenon is known as fatigue. The tears start where the metal is weakest, presumably at flaws, of which there are probably many of microscopic size in every piece of steel and iron. Experiments and experience indicate that during the life of structures, as determined by other considerations, failure from fatigue does not occur in steel and wrought iron of good quality under repeated stresses less than the elastic limit; but experiments also indicate that such failure is likely to occur under a long-continued succession of rapidly alternating stresses of intensity less than the elastic limit.

For the conditions of ordinary railway bridge practice, the provision for alternate stresses specified by the American Railway Engineering Association seems to be reasonable.

With proper treatment, steel or wrought iron can have its elastic limit raised by over-straining, as in cold-drawn and cold-rolled steel or iron, considerably above the yield point of the ordinary hot-rolled or forged metal; this fact is of great advantage to the manufacturer, and is useful in adjusting and increasing the capacity of some structural parts subjected to bending stresses, but of little value to tension and compression members in service, as the great elongation or compression when a member is strained above the yield point will cause failure of the member, or the entire structure, from distortion, and thus preclude the possibility of subsequent benefit from an enhanced elastic limit.

Fatigue formulas, so-called, have been devised, which are intended to give the greatest strength which can be developed in a piece of steel or wrought iron by straining without resulting in ultimate failure from fatigue. As the greatest strength of steel or wrought iron under repeated stresses is beyond, and in some cases far beyond, the yield point, such a formula, even if perfect, would not be applicable to the design of structural tension and compression members.

General Description of Steel and Wrought Iron.

Steel and wrought iron are essentially iron containing carbon in quantity not exceeding about 0.3% in wrought iron, usually less than 0.9% in steel, much less in structural steel, and not exceeding 2.2% in any steel. Other constituent and foreign substances are always present, some designedly and some unavoidably, some beneficial and some harmful.

Wrought iron differs from slagless steel in the limit to the percentage of carbon, in containing slag, and in being produced by the welding together of small slag-bearing masses, instead of being cast from a melt before rolling or forging. It differs from slag-bearing or weld steel, a now little used kind, in containing less carbon. Steel and wrought iron have a crystalline structure in which the crystalline formation has been more or less interfered with by treatment.

In general, treatment of steel and wrought iron is chemical, metallurgical, thermal, and mechanical. Mechanical treatment is possible because these metals are plastic; that is, they are capable of being more or less moulded by force, even when cold.

Whenever structural steel and wrought iron are strained beyond their elastic limits they are thereby treated to their benefit or injury.

The effect of stress in a piece of steel or wrought iron is to alter its size and shape temporarily, if the stress is within the elastic limit, or permanently, if beyond it, and, if beyond it, to alter the properties of the metal.

Elasticity.

Elasticity, as applied to solids, is the property of returning to original size and shape on removal of stress.

Proportionality of alteration in size and shape to stress is not essential to the conception of perfect elasticity, but experiments indicate that when the elasticity is perfect and the stress is simple tension or compression, such proportionality actually exists. When the stress is compound, the alteration in length in the direction of any one of the stresses is not the same as it would be under a simple stress in that direction, but if all the stresses are increased or decreased in any given proportion, within the elastic limit, the alterations in size and shape will be in the same proportion.

As regards elasticity, steel and wrought iron are isotropic; that is, when their elasticity is perfect, it is the same in all directions around any point.

The ratio of simple stress to alteration in length is expressed by a factor called the modulus of elasticity; this may be defined as one million times the simple stress per square inch required to increase or decrease the length of a bar the one-millionth part of its length.

Many carefully conducted experiments indicate that, at ordinary atmospheric temperatures, the modulus of elasticity of slagless steel, in either tension or compression, does not vary much from 30 000 000 lb. for all grades. (This is the technical way of stating that it takes about 30 lb. per sq. in. to stretch or compress such steel the one-millionth part of its length, as shown in Table 1.) Wrought iron, doubtless on account of the included slag with which the iron is intimately associated, has a somewhat lower modulus, and the same is probably true of slag-bearing or weld-steel, which is made, what little there is of it, from wrought iron without melting.

There are numerous tests in which the recorded alterations in length seem to indicate erratic variations of considerable magnitude in the modulus of elasticity, but they are probably either in error, or, on account of disturbing elements, are not applicable to the determination of the modulus. Additional and conclusive experiments in this regard are a desideratum.

Simple longitudinal tension, in addition to causing longitudinal elongation, causes lateral contraction; and simple longitudinal compression, in addition to causing longitudinal shortening, causes lateral expansion. The ratio of contraction or expansion, perpendicular to the direction of the stress, to elongation or shortening in the direction of the stress, is termed Poisson's ratio. If the bulk of a body is assumed to increase with pull and decrease with pressure, applied in either one or all directions, Poisson's ratio must be less than $\frac{1}{2}$. For instance, if equal pressures were applied on the six faces of a cube, and Poisson's ratio were more than ½, then the expansion in the direction of each pair of forces from the combined influence of the other two pairs would be more than ½ plus ½ of the shortening, or greater than the shortening, thereby increasing all the dimensions and the bulk of the cube; or, if Poisson's ratio were just ½, there would be no increase or decrease; but, if less than ½, there would be a decrease in bulk.

TABLE 1.—COMPARATIVE TESTS IN TENSION AND COMPRESSION OF 1¼-IN. DIAMETER OPEN-HEARTH STEEL BARS OF VARIOUS GRADES, TURNED TO SPECIMENS FROM THAT SIZE.

Compression Specimens 1.0092 in. Diameter, 12 in. Long.
Tension Specimens, 1.0092 in. and sundry Diameters; Gauged Length, 30 in.

Tests made at the Watertown Arsenal, and given in the Reports for the Year 1886, pp. 1635-1653; and for 1887, pp. 802-822.

Marks.	Composition, Percentage of:			Modulus of Elasticity.		Elastic Limit.		Yield Point.*	
	C.	Mn.	Si.	Compression, in pounds per square inch.	Tension, in pounds per square inch.	Compression, in pounds per square inch.	Tension, in pounds per square inch.	Compression, in pounds per square inch.	Tension, in pounds per square inch.
833	0.09	0.11	....	30 120 000	30 151 000	30 500	30 000	32 125	30 500
123	0.20	0.45	....	30 303 000	30 151 000	37 000	39 500	39 190	39 500
782	0.31	0.57	....	30 612 000	30 000 000	44 500	46 500	45 500	46 500
795	0.37	0.70	....	31 250 000	30 151 000	47 000	50 000	50 875	50 000
805	0.51	0.58	0.02	30 075 000	30 000 000	57 000	58 000	58 000	58 000
797	0.57	0.93	0.07	30 201 000	30 104 000	55 500	55 000	Not defined.	56 000
823	0.71	0.58	0.08	31 034 000	30 088 000	55 500	57 000	"	58 000
750	0.81	0.56	0.17	30 000 000	29 923 000	74 500	70 000	"	Not defined.
756	0.89	0.57	0.19	30 612 000	29 864 000	76 500	75 000	"	78 000
334	0.97	0.80	0.28	30 822 000	29 817 000	83 000	79 000	"	80 000

* The yield points are not specifically noted in the records, but in most cases are indicated: in tension, by increase in elongation under reduced loads and by great differences in elongations recorded for slightly differing loads; and, in compression, by buckling to failure after a slight increase in rate of shortening.

Poisson arrived at the existence of this contraction or expansion, at right angles to pull or pressure, from theoretical considerations; and his theory led him to assign to his ratio a value of ¼, but his theory has been questioned. Experiments indicate that the value for steel is between ¼ and ½.

The behavior of an isotropic elastic solid body, strained within the limits of its elasticity, is entirely determined by its modulus of elasticity and Poisson's ratio. Writers on theoretical mechanics have found it convenient to introduce other constants, but they are not needed for the purposes of this paper.

Elasticity is one of the most useful properties of matter. Without it, structures and machines would be impossible. It is the foundation on which many useful engineering theories are based, and it affords the mathematically inclined endless possibilities for intricate analysis, but to the practical engineer the most important question regarding it is its limit. The limits to the elasticity of steel and of wrought iron are closely related to the resistance of these metals to shear.

SHEAR.

The internal forces acting on any plane within a body can be resolved into a tension or compression at right angles to the plane—that is, normal to it—and a shear tangential to it.

When the force is a simple pull or pressure on a bar, as in Fig. 1 (drawn for pressure), the tension or compression has a maximum intensity, and the shear is zero, on a plane normal to the direction of the force; and the shear has a maximum intensity on a plane making an angle of 45° with the normal plane.

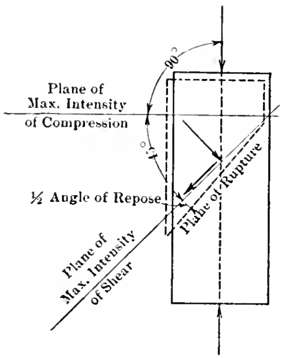


FIG. 1.

Experiments show that materials which are brittle or comminuible, "when subjected to a compressive load, fail by shearing on certain definite angles. The resistance to movement along these angles is made up of two parts; first the strength of the material to resist shearing; and second, the frictional resistance to motion along this plane." Analysis leads to the conclusion that rupture should take place on a plane making an angle with a normal plane of 45° plus one-half the angle of repose of the material. The analysis on which this conclusion is based* is supported by the results of numerous experiments and photographs of the specimens after rupture.

* J. B. Johnson's "Materials of Construction", pp. 24–28.

Under pressure, plastic materials, like structural steel and wrought iron, do not fail by shearing on any one plane, like the specimen in Fig. 1; but, after the elastic limit is passed, they simply spread, as in Fig. 2. Under pull, after the elastic limit is passed, they draw out like taffy, as in Fig. 3, to a greater or less extent, before rupture.

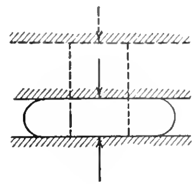


FIG. 2.

The fact that the deformation of materials depicted in Figs. 2 and 3 was caused by failure to resist shear is not evident from simple observation.

The usual conception of movement under shearing stress is that of sliding, but there is no visible evidence of the sliding of one particle on another before the elastic limit is reached. Change in shape within the elastic limit is not due to any sliding over one another of the individual grains or crystals; instead of this, each grain, no matter how minute, is itself deformed. What takes place among the molecules of the material under shear is a matter of speculation.

When the elastic limit is exceeded, the ensuing deformation is caused largely by actual sliding of the particles.

FIG. 3.

"These slips are seen under the microscope as sharply defined lines which appear on the polished surface of each grain as soon as the yield-point in any process of straining has been reached."*

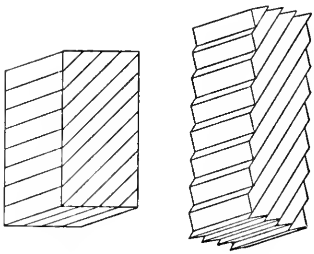
Of course, it is impossible to know or illustrate just how the particles move and slide in deformation beyond the elastic limit, but equivalent movements and slips can be conceived to illustrate how the geometry of such deformation can be accounted for on the hypothesis of sliding and rotating particles, as follows:

A square bar, made up of layers inclined at an angle of 45°, as in Fig. 4 (*a*), could be elongated longitudinally and contracted laterally by rotating the layers and sliding them over one another, as in Fig. 4 (*b*). Two of the sides of such a bar would not be plane, but, if the layers were very thin, the surfaces would appear to be plane with fine markings.

* James Alfred Ewing in Encyclopædia Britannica, 11th Ed., Vol. XXV, p. 1018.

Such a bar would be contracted in only one lateral direction, whereas bars under simple pull are contracted in two lateral directions perpendicular to each other. This defect in the supposititious bar can be remedied by conceiving the bar as divided into a large number of equal small bars, each, in turn, divided into inclined layers, as in Figs. 4 (*a*) and 4 (*b*), but grouped so that the inclined edges of the layers in one set of small bars would be adjacent to the horizontal edges in another set, as in Fig. 5.

If the small bars into which the large bar is conceived as divided are very small, and the surface of the large bar is conceived to be polished, the edges of the layers would appear as straight lines. The angles which these lines would make with a plane normal to the direction of the pull would have a tangent equal to ½ tan. 45°, or 0.5,



(*a*) (*b*)

FIG. 4.

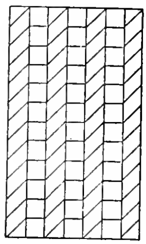


FIG. 5.

which corresponds to an angle of 26° 34′. Such lines are known as Luder's lines. Their occurrence in pulling tests, as indicated in specimens of full thickness by the breaking of the mill scale, is a very common phenomenon. It is evident from simple inspection that the angle these lines make with a plane normal to the direction of the pull is usually much less than 45° and not often far from the angle of 26° 34′ as just deduced. Before this deduction was made, Professor Ewing* stated that this angle had been found to be about 25 degrees. Two sets of Luder's lines, sloping in opposite directions, appear in tests, which shows that the actual condition is more intricate than the equivalent condition assumed. The condition assumed, however, makes it evident that the lines do not directly indicate the slopes of the planes on which slipping occurs, but instead, the mean inclinations of the edges of the planes.

* Encyclopædia Britannica, 11th Ed., Vol. XXV, p. 1016.

Lateral expansion under longitudinal pressure can be accounted for in a manner similar to that for lateral contraction under longitudinal pull.

The foregoing explanation of deformation under pull raises the question: What holds the grains together in tension after they sever their original connections and rotate and slide? The answer involves a consideration of the nature of the change which occurs in the condition of steel and wrought iron when the limits to elasticity are exceeded.

The Elastic Limit.

Material which can be constrained by mechanical force into new forms without breach of continuity is said to be plastic; hence, wrought iron, soft steel, and, to some extent, even hard steel, are plastic. They are seldom characterized as plastic, but wrought iron and soft steel are described as malleable and ductile, which terms imply a great range of plasticity. Some of their characteristics while flowing are those of a liquid.

Liquids have no resistance to shear, but have cohesion* among their molecules, which is nil at their boiling point and increases toward their freezing point.† Cohesion without resistance to shear does not prevent but does impede flowing, and this property is termed viscosity. Liquids, however, are not usually termed viscous unless they possess a high degree of viscosity. Viscous liquids not only have cohesion, but, to a greater or less extent, have the property of adhering to solids. This useful property, this glue-like stickiness, though not essential to the scientific conception of viscosity or included in the scientific definition of the term, is firmly ingrained—in fact predominates—in the popular idea of the meaning of the word. Above certain temperatures, and at ordinary temperatures under certain mechanically produced conditions, viscous portions of structural steel and wrought iron adhere strongly to the solid portions of the metal.

According to some physicists, the plastic solid is distinguished from the viscous liquid in that the former requires a certain magni-

* Newton devoted the 31st query in the last edition of his "Opticks" to molecular forces, and instanced several examples of cohesion of liquids, such as suspension of mercury in a barometer tube at more than double the height at which it usually stands.

† The surface tension diminishes as temperature rises, and when the temperature reaches that of the critical point at which the distinction between a liquid and its vapor ceases, it has been observed by Andrews that the capillary action also vanishes. James Clerk Maxwell, and Lord Rayleigh in Encyclopædia Britannica, 11th Ed., Vol. V, p. 261.

tude of stress to be exceeded to make it flow, whereas the viscous liquid will yield to the slightest stress, but requires a certain length of time for the effect to be appreciable. This distinction is generally accepted, but is superficial.

The change from a solid to a liquid state is a radical one. Considerable energy, usually in the form of heat, is required to melt the solid, which energy is not expended in raising temperature, but in effecting molecular changes by reason of which the potential resistance to flowing is overcome and the molecules are less restricted and have greater freedom of action. It is this difference in molecular arrangement, no matter how produced, which is the real distinction between a liquid and a solid.

A certain portion of a plastic metal, when caused to flow by "a certain magnitude of stress", is a highly viscous liquid during the continuance of the flow, and even for a time after the removal of the stress; and it will be so termed in dealing with this subject.

Mr. H. E. Tresca, by applying great pressure, caused copper, silver, iron, and other metals to flow, like viscous liquids, through a small circular aperture at the bottom of a cylinder, and without breach of continuity. Parallel experiments, with layers of dough or sand plus some connecting material, proved that the particles moved along the same tracks as would be followed by a flowing cylinder of liquid.*

When structural steel and wrought iron become partly viscous and begin to flow, the elastic limit, of course, has been reached; and the converse is true: when the elastic limit is reached, structural steel and wrought iron become partly viscous and begin to flow. It is because the viscous portion of the metal acts somewhat like glue does with wood, or china cement with china, that the sliding grains or crystals adhere in their new positions, and finally, after the viscous portion has solidified, form a coherent mass.

When structural steel and wrought iron are strained for the first time after leaving the rolls or forge they are apt to have slight imperfections in elasticity, indicated by slight permanent sets, under loads far below those at which the general yield begins.

Structural parts are strained so frequently that even very slight permanent sets, if repeated and accumulative, would become ruinous

* Encyclopædia Britannica, 11th Ed., Vol. XVIII, p. 199.

in a comparatively short time. For reasons discussed in the next section—The Beneficial Effects of Strain—such increases in permanent sets, under loads below that at which the general yield begins, do not occur, and slight imperfections under such loads are of little practical importance.

Structural steel and wrought iron are not minutely homogeneous with respect to resistance to shear; that is, although small specimens of metal of good quality are nearly alike, microscopic specimens differ; but, for a considerable proportion of the metal within a specimen, the resistance is so nearly uniform that, after a certain point in stress is reached, a general yield develops under a slight increase in stress intensity.

In simple tension or compression, the yield usually culminates in a flow under a constant or decreasing force at a point called the yield point. At this point, in slowly conducted tests, the intensity of the stress frequently decreases several thousand pounds, in extreme cases as much as 10 000 lb. per sq. in.; after which it takes an increasing force to cause the metal to flow with any degree of rapidity. In some tests, the yield point is indicated by a relatively great increase in elongation or shortening under a slight increase in stress.

In ordinary specimen tests, the yield point is usually discernible by the drop of the beam, unless the steel is hard and the speed rapid. The yield point is often called the elastic limit, for the reason that in ordinary testing it is the first indication that the elastic limit has been reached. By some authorities it is called the apparent elastic limit; but yield point is the best name.

The beginning of the general yield sometimes coincides with the yield point; that is, in such cases, the general yield develops instantaneously to a flow without increase in load. More often the beginning of the general yield occurs under a stress from a few hundred to a few thousand pounds per square inch below the yield point, and is indicated by increase in rate of elongation or shortening, which increase is discernible in ordinary specimens by measuring carefully the elongation or shortening with sensitive micrometers.

By some authorities, the beginning of the general yield is called the proportional elastic limit, or the limit to proportionality, for the reason that, below this point, the elongation or shortening indicated in simple tension and compression tests is nearly proportional to stress, even on the first application of the load. In the detailed reports of the many scientifically conducted tests at the Watertown Arsenal, this point is called the elastic limit; which is the better name for it, for three reasons: first, the elasticity of the metal up to this point can be perfected by straining, as explained in the next section—The Beneficial Effects of Strain; second, the permanent sets below this point do not increase under repeated or continued stresses, and are too slight to be of any practical importance; third, proportionality of elongation or compression to stress is not the essential but simply an observed characteristic of elasticity.

When the gauged lengths are long and the measurements are made with great precision, the true elastic limit, as some authorities term it, is usually very low the first time the metal is strained; in many cases it has been observed to be as low as 5 000 lb. per sq. in. This point, for reasons explained in the next section, is of no practical importance. It is doubtful, in fact, whether, when structural steel and wrought iron are strained for the first time, there is any point below which elasticity and proportionality are absolutely perfect.

The elastic limit, defined as the beginning of the general yield, is the most important measure of the most important property of structural steel and wrought iron, because it is the criterion of permanent strength without, or with only slight, permanent deformation, and because it is the limit to the applicability of those methods of determining stresses and deformations which are based on the proportionality of stresses to deformation.

Experiments have shown that the yield point and elastic limit of structural steel and wrought iron are practically the same in compression as in tension. As this fact is crucial in explaining what takes place at the elastic limit, the results of pertinent experiments are given in Tables 1 and 2. The tests in Table 1 are part of a series of scientific experiments made by the Government's engineers at the Watertown Arsenal, and are notable for their precision and the wide range of grades covered—from carbon 0.09 to 0.97 per cent. The tests by the late Charles A. Marshall, M. Am. Soc. C. E., in Table 2, are part of what was probably the most exhaustive comparison of steel and wrought iron in compression with steel and wrought iron in tension. For both of these metals all his results are substantially in accord with those in Table 2.

TABLE 2.—COMPRESSION AND TENSION TESTS OF STEEL BARS, ALL FROM THE SAME BLOW OF BESSEMER STEEL "AS FROM ROLLS".

Tests made by the late Charles A. Marshall, M. Am. Soc. C. E. *Transactions,* Am. Soc. C. E., Vol. XVII, p. 68.

Pieces for Tension Tests cut from same bars used in Compression Tests. All tests were of full-sized bars, except specimens tension tests of 3-in. bars more than 1 in. thick. Bars tested in compression had flat ends.

$$\frac{l}{r} = \frac{\text{Length}}{\text{Radius of Gyration}}.$$

	COMPRESSION.									TENSION. ELASTIC LIMIT "BY BEAM"; GAUGED LENGTHS, 8 TO 25 INCHES.	
	ELASTIC LIMIT.	ELASTIC LIMIT, "BY BEAM"†—WHICH IN THESE TESTS WAS ALSO FAILURE BY YIELDING AND BENDING.									
Length....	2 Diameters.	30 and near 30 Diameters.		24 Diameters.		18 and near 18 Diameters.		12 and near 12 Diameters.			
Size of bar, in inches.	Pounds per square inch.	$\frac{l}{r}$	Pounds per square inch.	$\frac{l}{r}$	Pounds per square inch.	$\frac{l}{r}$	Pounds per square inch.	$\frac{l}{r}$	Pounds per square inch.	Number of tests averaged.	Pounds per square inch.
¾ round.	47 300	....	......	....	......	....	......	50	44 980	4	46 090
1 "	46 020	....	......	....	......	....	......	48	44 000	4	44 202
1¼ "	43 460	....	......	....	......	....	......	48	40 850	3	40 747
1½ "	41 290	....	......	....	......	....	......	48	41 880	3	40 275
1¾ "	42 075	....	......	....	......	....	......	48	39 950	3	40 017
2 "	38 830	....	......	....	......	....	......	48	40 850	3	38 207
2¼ "	38 125	....	......	....	......	72	36 580	48	36 790	1	37 000
2½ "	36 840	....	......	....	......	70	34 450	48	35 650	1	36 100
¾ square	43 845	....	......	....	......	....	......	45	44 960	3	44 273
1 "	44 025	....	......	....	......	....	......	42	43 080	3	43 560
1¼ "	42 300	....	......	....	......	....	......	42	40 060	3	41 060
1½ "	42 740	....	......	....	......	....	......	42	38 420	3	39 317
1¾ "	40 630	....	......	....	......	....	......	42	39 450	3	38 193
2¼ "	39 940	....	......	....	......	63	37 330	42	39 270	1	38 310
3 by ⅜....	......	....	......	83	46 150	63	46 420	42	47 650	3	47 363
3 " ½....	......	104	42 170	83	43 490	....	......	42	41 650	3	44 417
3 " ¾....	......	102	40 700	....	......	....	......	42	43 580	3	41 447
3 " 1	......	....	......	83	36 920	....	......	42	41 200	3	39 397
3 " 1¼...	......	....	......	.. .	......	63	35 430	39	38 350	4	38 482
3 " 1½...	......	....	......	....	......	....	......	42	36 920	4	37 820
3 " 1¾...	......	....	......	....	......	....	......	42	35 760	4	35 917
3 " 2 ...	......	....	......	....	......	....	......	42	37 670	4	39 302
*4 " ½....	......	104	51 210	83	55 320	63	55 110	42	55 420	2	53 800
4 " 1	......	104	39 270	....	......	....	......	42	42 630	2	41 415
4 " 1¼...	......	....	......	83	38 200	....	......	42	39 300	1	36 680
4 " 1½...	......	104	39 100	....	......	63	39 850	42	39 500	1	37 580
							Average.....		41 147	.....	40 807

NOTES.—Results for specimens 2 diameters long are the average of two tests each, except for ¾ in. round and 1 in. square. All other results in compression are those of single tests. "The short compression specimens were removed and measured with a measuring machine." "The tendency is with very short specimens, either in tension or compression, to get too high values for elastic limit."

* "Bar finished at very low heat."

† Elastic limit "by beam" is now frequently termed yield point, which is better practice, as the point properly termed elastic limit and sometimes termed proportional elastic limit is usually somewhat lower.

This equality of the yield point in tension and compression shows that resistance to flowing is just as great when there is a pull normal to the direction of the shear as when there is a pressure. It seems fair, therefore, to infer that flowing occurs just as soon as, and not before, the resistance to shearing is overcome, uninfluenced by the kind (tension or compression) or intensity of the normal component, and irrespective of whether the shear was produced by simple or compound stresses. What seems to be a yielding to simple tension or compression is really a flowing under shear.

The question whether maximum stress, maximum strain (linear), or maximum shear is the critical consideration has been much debated during the last fifteen years. That shear is the critical consideration is supported by the experiments and analysis of J. J. Guest,* Professor E. L. Hancock,† and others. For plastic materials, the conclusion seems inevitable that shear is the critical consideration as regards the elastic limit. Frictional resistance, which in cases of comminuible materials supplements resistance to shear, cannot be much of an element in the flowing of plastic metals, for the reason that the flowing metal is either all viscous liquid or solid particles mixed with and well lubricated by viscous liquid. There is no friction between the particles of a liquid; otherwise they could be permanently piled, like sand or coal.

In cases of simple tension and compression, it is the custom to state the elastic limit in terms of the intensity of the tension or compression. This custom is simple, and it is not advisable to attempt to change it, even though it is not tension or compression but shear that is critical. It is well, however, to be able to state for plastic metals the elastic limit in terms of shear intensity, so that it can be generally applied to compound as well as simple stresses. From the fact that the maximum shear occurs in a plane making an angle of 45° with the direction of a simple tension or compression, it can be readily shown that the quantity which expresses the elastic limit in terms of shear intensity is one-half the quantity which, in cases of simple tension or compression, expresses the intensity of the tension or compression at the moment the elastic limit is reached. For instance, if the elastic limit for a certain quality of steel has been definitely found by

* *Phil. Mag.*, July, 1900.

† *Phil. Mag.*, 1906, Vol. XI, p. 276, and Vol. XII, p. 418.

tension tests, and appears to be 36 000 lb. per sq. in. in tension, it really is 18 000 lb. per sq. in. in shear; and, under whatever condition of loading, simple or complex, when the shear reaches 18 000 lb. per sq. in., and not before, the elastic limit in this precise quality of steel will be reached.*

If steel or wrought iron should be pulled equally in all directions, there would be no shear, so that failure, if it occurred, would take place without any preliminary elastic limit; but there is no known way of making such a test.

Hydrostatic pressure, which, of course, is equal in all directions, has been applied to mild steel, wrought iron, cast iron, drawn brass, and drawn copper, in experiments at the Watertown Arsenal.† The pressure was estimated as 90 000 lb. per sq. in., except for one steel specimen for which it was 117 000 lb. per sq. in. The permanent effect of compression on the dimensions of the specimens was not appreciable with the steel, brass, and copper. The wrought iron and cast specimens after testing were smaller, but, as the reduction in dimensions did not take place uniformly, the effect was attributed to the closing of interstices formed by blow-holes, or the presence of cinder. A comparison of the results of tests shows no appreciable change in the strength, elasticity, and ductility of the compressed over the uncompressed metal.

The Beneficial Effects of Strain.

Between the temperatures at which iron and ordinary steel (containing less than 0.9% of carbon) are entirely liquid and the temperatures at which they are entirely solid there is a great range, for the major part of which the metal is technically a solid, because it requires stress exceeding a certain magnitude to produce continuous alteration of form. It does not follow, however, that the metal is all solid. It will answer the description of "plastic" if it consists of an intimate mixture of liquid and solid particles in which the solid particles are sufficiently connected to give the mass strength to resist a limited amount of shear. There are many plastic solids, such as putty, plaster, mud, and modeling clay, which are solid, according to

* This fact should be applied with caution. Quality varies, even within the same piece, and actual intensity is partly dependent on unknown initial internal stress; hence, the nominal stress intensity at which the elastic limit occurs is subject to variation in metal of nominally uniform quality.

† Report for 1886, pp. 1663, 1687.

the usual distinction between a viscous liquid and a plastic solid, but which, nevertheless, are part liquid and part solid. From the fact that changes take place in plastic iron and steel, within a certain range of temperature, which parallel those which take place in the viscous liquid state, it is highly probable that within this range the metal consists of an intimate mixture of solid particles, sufficiently connected to make the mass as a whole solid, and a highly viscous liquid which, like pitch, looks solid and adheres to the strictly solid portion. Be this as it may, a portion of the metal is a viscous liquid when it flows under pressure or pull.

According to metallurgists, as iron and steel with less than 0.9% of carbon slowly cool, the iron solidifies in first one and then another potentially hard, strong form containing carbon in solid solution, like sugar in gelatin, until a stage in the process of solidifying is reached, between 700 and 900° cent. (about 1 290 and 1 470° Fahr.), during which the iron expels the carbon and assumes a softer, weaker, pure form; the carbon combines with iron, forming cementite, Fe_3C, harder than glass and nearly as brittle, but probably very strong; the two substances minutely interstratify, in the proportion of six parts of iron to one part of cementite, and thus form a substance termed pearlite; and the pure iron and pearlite intimately mix. The changes at the end of this stage evolve so much heat that the mass is heated, and brightens in a striking manner. This phenomenon is called the "recalescence".

Slow cooling, through the stage at the end of which recalescence occurs, gives full opportunity for changes in the form of the iron and in the mixtures which result from the presence of carbon, and it facilitates the growth of crystals and of a coarse crystalline structure. These developments can be arrested or modified by hastening the complete solidification by sudden cooling, thereby producing in most cases a stronger steel than is obtained when the metal is allowed to cool slowly. The addition of certain elements, as in some of the alloy steels, will similarly arrest or modify the transformations.

It is not known to what extent steel or wrought iron made viscous by strain is similar in condition to the same metal at some high temperature, but it possesses one of the important characteristics of such hot metal—its sudden solidification makes for hardness and strength.

Structural steel and wrought iron during their manufacture are slowly cooled, undergo one or more reheatings, and are subject to mechanical force while cooling. The metal is an intimate mixture of particles which differ in their capacities to resist shear, though in most cases a considerable proportion forms a matrix which is nearly homogeneous in this respect and has disseminated throughout its mass the more or less connected stronger grains.

All structural steel and wrought iron, before the metal is strained in service or tests, contain in their free state some balanced initial internal shears produced by unequal cooling and the processes of manufacture. Therefore, when strained by an external load, the real intensity of the shear at any point is that of the apparent shear plus the initial internal shear. When this combined shear exceeds the shearing resistance of the metal, the latter becomes viscous and flows, thus relieving the initial internal shear, but causing a permanent set. When, in such cases, the load is removed, the viscous metal resolidifies at a temperature far below its natural freezing point, and acquires thereby a very much greater shearing resistance, so that if, after a rest, a load in the same direction is again applied, the elasticity will be perfect up to the limit of the former loading. If the loading is carried beyond that limit, it will be some other portion of the metal not previously over-strained which will be the first to yield under the new loading.

In this way steel and wrought iron structural parts not subject to alternate stresses can have their elasticity perfected to the beginning of the general yield—the point known as the elastic limit. This conclusion agrees with Bauschinger's experiments, and harmonizes with the general trend of the experiments at the Watertown Arsenal; but the most satisfactory evidence of its substantial accuracy is the behavior of structures in service which, under frequently repeated and long continued heavy loads, give no evidence of any growth in permanent set so long as the strains are below the point at which the general yield would begin. It is possible that elasticity is similarly perfected to the same point in parts subjected to alternate stresses, but, for reasons explained in the next section—Fatigue—it is advisable to use, for such parts, a somewhat lower point as the criterion of permanent strength.

The elasticity can be perfected by over-straining, and the elastic limit raised thereby, even when the over-straining is carried beyond the original yield point; but this fact is of little practical importance to those structural members which are subjected primarily to direct tension or compression. The elongations and shortenings in such members are so great, after the yield point is reached, as to produce ruinous deformation in the structures of which such members are a part. In the case of compression members, unless they are very short, strain to the yield point means failure, as shown in Table 2.

The raising of the elastic limit by over-straining is of great use in manufacturing steel and wrought iron. It is this which gives to drawn wire, drawn steel, and cold-rolled steel their enhanced strength; and it is partly by over-straining that hot-forging and rolling raise the elastic limit of the metal; though part of the virtue of these operations on hot metal is due to refinement of crystalline structure and to the closing of cavities by bringing their sides to a welding contact. In all these manufacturing processes, to achieve good results, it is essential that the over-straining should not be too great, as explained in the next section—Fatigue.

When strains in steel and wrought iron are produced by transverse loading, there are special features by reason of which the effect of such strains requires separate consideration. These features are as follows:

First.—The distribution of stress, in cases of transverse loading, is too complicated a problem to admit of precise determination. The ordinary theory of flexure, even within the limits of perfect elasticity, is only an approximation.* It neglects the influence of distortion from shear on distribution of stress, and, in consequence, the stress in the extreme fiber is greater, so long as the elasticity is perfect, than the ordinary theory indicates. This is especially the case with short beams, having thin webs, under heavy concentrated loads.

Second.—The beginning of the general yield, as distinguished from imperfections in elasticity due to initial internal stresses, is not well marked.

* Professor A. E. H. Love on Elasticity in Encyclopædia Britannica, 11th Ed., Vol. IX, pp. 141–160; also, Prichard on "Faults in the Theory of Flexure, and an Epitome of Certain I-Beam Tests made at Ambridge, Pa.", *Transactions*, Am. Soc. C. E., Vol. LXXV, p. 895.

Third.—In consequence of the different distribution of stress, from that which obtains in cases of direct tension or compression, the progress and consequences of the yield are correspondingly different.

Consider the case of a horizontal round or square bar loaded vertically; when the load is such that stresses in the extreme fibers just equal the elastic limit, the intensity of the stresses will decrease nearly uniformly from the top and bottom toward a neutral axis at the center. When the load is increased, the elastic limit will be exceeded in some part of the extreme fibers, and they will become viscous and flow, thus relieving themselves of the stress in excess of such limit. The fibers immediately below the top and bottom ones will then be strained to their elastic limit, and the process will continue, when the load is sufficient, until, for quite a distance from the top and bottom of the bar, the metal at the critical portion of the span will be strained to its elastic limit and develop increased resistance accordingly. Moreover, the viscous metal will resolidify in stronger form. If the load is gradually taken off, the fibers toward the top and bottom will be entirely relieved of their stress before those nearer the center, after which tension will be developed in the top and compression in the bottom, forming a couple balanced by another and opposite couple nearer the axis; moreover, the bar will have a permanent deflection. If the load is again applied, the effect of taking off the load will be reversed, without any additional over-straining, unless the former load is exceeded. In this way, at the expense of a little permanent deflection, the strength of the bar to resist transverse loading in one direction can be greatly enhanced; but, if the direction of the load is reversed, the balanced internal stresses will tend to lower the elastic limit of the bar.

The principles explained in the foregoing paragraph apply to all cases of transverse loading, but for beams, rolled or built, of I-section, the possibilities of enhancement of strength are not nearly as great as for those of round or square section, and may be offset by spreading the metal too thin.

Fatigue.

Fatigue, as applied to metals, is weakness produced by strain. It may be temporary or it may be permanent, and it may gradually increase under oft-repeated or long-continued stresses until it produces failure.

Structural steel and wrought iron made viscous by strain are extremely viscous; that is, their flow under stress is exceedingly slow. For instance, a wrought-iron bar, 1 in. square, tested as a horizontal beam, which had been made partly viscous by a gradually increasing center load during 8 days, was then loaded at the center with 2 589 lb. Under this load its deflection gradually increased during 61.5 hours from 4.2749 to 4.6701 in., at which point the weights reached the support and the test was discontinued.*

When a bar of structural steel or wrought iron is strained beyond its elastic limit, it becomes an intimate mixture of viscous liquid and elastic solid portions. After the load which produced the strain is removed, the solid elastic portion endeavors to resume its former size and shape, and would do so almost instantly were it not for the opposition of the viscous liquid which adheres to it and is compelled thereby to flow but which refuses to flow rapidly and, in consequence, is for a while subjected to a push or pull from the elastic solid portion, the return of which to its former size and shape is thus delayed.

The viscous portion of over-strained steel and iron may solidify even while the piece of which it is a portion is subjected to stress. For instance, the 1-in. square bar just referred to was loaded in the center, at one stage of the experiment, with 1 600 lb., and while thus loaded its deflection gradually increased during 16 min. from 0.489 to 0.6598 in., but then the viscous metal appears to have solidified, as there was no further deflection during the remainder of the 5 hours and 44 min. that the load remained unchanged.

Just as there is, for each elementary portion of structural steel and wrought iron at atmospheric temperature, a certain intensity of shear beyond which solid metal becomes viscous, so there is a certain intensity of shear beyond which viscous metal subjected thereto remains viscous and flows; but when the flowing releases the viscous metal from shear in excess of the critical intensity, it will resolidify. In cases where iron and steel have been strained to a point below that at which the general yield commences, but at which, by reason of initial internal stresses, a small portion of the metal has become viscous, the recoil of the large elastic solid portion on release of stress will act on the

* Report of U. S. Board on Testing Iron and Steel, Vol. 1, pp. 464, 469, and 471 (1881).

viscous portion, but with such low intensity and through such a short distance that it will not prevent rapid solidification.

On the other hand, in cases where the yield point has been somewhat exceeded, the stress intensity in the elastic solid portion of the metal will be very high, and, on the release of the stress, this solid portion, in its endeavor to regain its former size and shape, will push or pull some part of the viscous portion, causing it to remain viscous and slowly flow while the solid portion gradually recoils. This process will continue until the intensity of the shear resulting from the push or pull is reduced to a point below that required to prevent the solidification of the viscous portion.

Much of the recovery after over-strain takes place in a few minutes, and nearly all in a few hours; but, toward the very end, as the force from the recoil of the elastic solid portion of the metal approaches the intensity permitting complete solidification, the process becomes exceedingly slow, and may continue for many days. At this stage, it appears, from experiments by Mr. J. Muir, that the shear exceeds the resistance of the viscous portion of the metal to flowing by such a narrow margin that the changes incident to a slight increase in temperature will turn the scale. He found that pieces of medium steel which normally required a long rest to recover their elasticity at atmospheric temperature, after being over-strained in tension, recovered it in a few minutes when exposed to the temperature of boiling water.*

Straining metals beyond their elastic limit and thus causing them to flow, as explained in the section on Shear, implies a rotation of one group of solid elements through a definite angle with respect to another group of such elements. This tends to create minute interstices between solid elements. These interstices have to be filled with viscous metal to act as cement, or there will be cavities and cracks. If iron or steel is not very ductile, so that only a small portion becomes viscous under high stress intensity, or if it is ductile but so overstrained that the viscous portion will not fill the interstices, the overstraining will develop permanent cavities and cracks, which nothing but heating will remedy. In fact, iron and steel can be strained, even when at welding heat, to an extent which develops flaws which nothing short of remelting can remedy.

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* Muir "On Recovery of Iron from Overstrain", *Phil. Trans.* A, Vol. 193, (1910).

With respect to strain, hot steel (or hot wrought iron) differs from cold steel (or cold wrought iron) in having a lower elastic limit, in offering less resistance to deformation under stresses in excess of the elastic limit, and in affording opportunity for simultaneously over-straining, welding, and heat treatment. It is possible that some of the alloy steels owe their good qualities in part to an influence in the hot metal whereby it permits and receives greater over-straining under good welding conditions than in ordinary steel.

Blow-holes, foreign substances (such as sulphide of iron and graphite), and cavities and cracks, caused by over-straining while cold or hot, break the continuity of the metal and thereby weaken it. Probably no steel or iron is free from such flaws, though in metal of good quality it requires a microscopical examination to discover them. These breaks in the continuity of the metal cause the stress to be concentrated at their edges, and it is in this way, much more than by reducing the effective cross-sectional area, that these flaws weaken the metal in which they occur.

It is common experience that the easiest way to break a small piece of metal is to bend it alternately backward and forward. Similarly, by straining bars alternately in tension and compression, as in a rotating shaft, a small crack can be extended by stresses locally until it becomes a plane of rupture without much preliminary evidence of a general yield.

"In experiments by Ewing and J. C. W. Humfrey ('The Fracture of Metals under repeated Alternations of Stress,' *Phil. Trans.,* 1903) the microscope was employed to examine the process by which metals break through 'fatigue' when subjected to repeated reversals of stress. The test-pieces were short rods overhanging from a revolving mandrel and loaded at the end so as to produce a bending moment. A part near the support, where the stresses due to bending were greatest, was polished beforehand for observation in the microscope. After a certain number of reversals the surface was examined, and the examination was repeated at intervals as the process continued. The material was Swedish iron following Hooke's law (in tension) up to 13 tons per sq. in. and having a well-marked yield-point at 14.1 tons per sq. in. It was found that the material suffered no damage from repeated reversals of a stress of 5 tons per sq. in., but that when the greatest stress was raised to 7 tons per sq. in. incipient signs of fatigue began to be apparent after many reversals, though the piece was still intact after the number of reversals had reached three millions. With a stress of 9 tons per sq. in., or more, repeated reversals brought about fracture. The first sign of fatigue as detected in the microscope was that slip lines began to appear on one or more of the crystals in the region of greatest stress: as the process went on these became more distinct and tended to broaden, and at length some of them developed into cracks which were identified as such because they did not disappear when the surface was repolished. Once a crack had formed it quickly spread, and finally the piece broke with a sharp fracture, showing practically no plastic change of form before rupture."*

Probably the most extensive series of experiments with rotating shafts were made at the Watertown Arsenal during a period of ten or more years prior to 1908. A synopsis of some of these experiments—a great many tests of hot-rolled open-hearth steel bars—is given in Table 3. It is interesting to note that in one case the fracture started from a slight indentation and in another case from a slight scratch on the surface of the shaft. With the exception of 0.73% carbon steel, the pulling tests showed well-marked yield points, either at the elastic limit or very slightly above. The results of pulling tests from ruptured bars agreed substantially with those of the auxiliary pulling tests, except for a slight decrease in elongation. The 1.09% carbon steel failed under alternating stresses of an intensity 51.9% of the elastic limit. Omitting this steel from consideration, on account of its being much higher in carbon than steel used for structures, the lowest intensity, relative to the elastic limit, at which the steel failed in these endurance tests was 61.4% of that limit. The extreme intensities of the alternating stresses recorded in these tests were computed for static conditions, in accordance with the theory of flexure; but, as this theory gives results which, when the elastic limit is not exceeded, are too low, and as the shafts were rotating 500 times per min., the actual extreme intensities and their ratios to the elastic limit were, probably, somewhat greater than are given in the table.

An extensive set of experiments was made "On Resistance of Iron and Steel to Reversals of Direct Stress" by Thomas Ernest Stanton and Leonard Bairstow.† The specimens they used were tested by direct instead of bending stress. Table 4 gives the results of the critical tests, that is, those in which rupture occurred at the least

* James Alfred Ewing, in Encyclopædia Britannica, 11th Ed., Vol. XXV, p. 1019.
† *Minutes of Proceedings*, Inst. C. E., Vol. CLXVI, Part 4, 1906.

TABLE 3.—ENDURANCE TESTS OF ROTATING SHAFTS TURNED TO 1.009 IN. DIAMETER, FROM 1¼-IN. HOT-ROLLED BARS OF OPEN-HEARTH STEEL OF VARIOUS GRADES, AS FOLLOWS:

	Percentages.					
Carbon....................	0.17	0.34	0.55	0.73	0.82	1.09
Manganese................	0.57	0.65	0.75	0.64	0.36	0.39
Silicon	0.04	0.34	0.14	0.04	0.10	0.11

Length between supports, 33 in.,
Loaded over 4 in. length at middle,
Speed of rotation, 500 per min.

Compiled from Watertown Arsenal Reports for Years 1903-1908.

PULLING TESTS AUXILIARY TO ENDURANCE TESTS. GAUGED LENGTH, 4 IN.			Percentage of carbon.	ENDURANCE TESTS OF ROTATING SHAFTS.					
					ALTERNATE TENSION AND COMPRESSION.				
Test No.	Elastic limit, in pounds per square inch.	Tensile strength, in pounds per square inch.		Test No.	Maximum fiber stress, in pounds per square inch.	Percentage of elastic limit.*	Percentage of tensile strength.*	Number of rotations.	Result of test on shaft.
7 937	51 000*	68 000*	0.17	371	60 000	117.6	88.2	6 470	Ruptured.
			0.17	372	50 000	98.0	73.5	17 790	do.
			0.17	373	45 000	88.2	66.2	70 400	do.
			0.17	374	40 000	78.4	58.8	293 510	do.
			0.17	376	35 000	68.6	51.5	5 757 920	do.
			0.17	375	30 000	58.8	44.1	100 000 000	Not ruptured.
8 132	54 400*	85 000*	0.34	389	60 000	110.3	70.6	14 630	Ruptured.
8 133	54 200	84 200	0.34	390	50 000	91.9	58.8	69 350	do.
			0.34	395	45 000	82.7	52.9	166 360	do.
			0.34	412	40 000	73.5	47.1	63 667 320	do.†
7 938	57 000*	106 100*	0.55	377	60 000	105.3	56.6	12 490	Ruptured.
			0.55	378	50 000	87.7	47.1	93 160	do.
			0.55	379	45 000	78.9	42.4	166 240	do.
			0.55	380	40 000	70.2	37.7	455 350	do.
			0.55	381	35 000	61.4	33.0	900 720	do
			0.55	383	30 000	52.6	28.3	75 006 000	Not ruptured.
8 135	66 000*	141 200*	0.73	391	60 000	90.9	42.5	55 390	Ruptured.
8 134	64 000	140 200	0.73	392	50 000	75.8	35.4	238 212	do.
			0.73	396	45 000	68.2	31.9	7 254 010	do.‡
			0.73	417	40 000	60.6	28.3	58 400 000	Not ruptured.
7 944	63 000*	142 250*	0.82	382	60 000	95.2	42.2	37 250	Ruptured.
			0.82	384	55 000	87.3	38.6	93 790	do.
			0.82	386	50 000	79.4	35.1	213 150	do.
			0.82	387	45 000	71.4	31.6	605 460	do.
			0.82	388	40 000	63.5	28.1	202 000 000	Not ruptured.
8 137	77 000*	132 800*	1.09	393	60 000	77.9	45.2	17 540	Ruptured.
8 136	75 400	132 000	1.09	394	50 000	64.9	37.7	61 030	do.
			1.09	403	45 000	58.4	33.9	182 700	do.
			1.09	404	40 000	51.9	30.1	433 380	do.
			1.09	405	35 000	45.5	26.4	175 280 000	Not ruptured.

* Designates elastic limit and tensile strength used in computing percentages.

† Bar ruptured midway between middle bearings, at a score mark made by head of screw which holds up middle bearing fixture.

‡ Eccentric fracture at fine line scratched on the surface of the bar which was used for locating the position of the micrometer beam.

intensity of stress, and those which endured the greatest number of reversals of stress without rupture. In these tests, as in those described by Ewing, microscopical examination during their progress showed that failure was caused by the gradual development of cracks.

The tests recorded in Tables 3 and 4 have a direct bearing on the strength of moving parts of machinery. As regards wrought-iron and steel structures, although the conditions are not precisely analogous, it may be inferred that a somewhat similar fatigue would occur, in those parts which are subjected to frequent alternations of stress, if certain limits less than the elastic limit were exceeded. In structural

TABLE 4.—Resistance of Iron and Steel to Reversals of Direct Stress.

Compiled from Stanton and Bairstow's paper in *Minutes of Proceedings*, Inst. C. E., Vol. CLXVI, 1906, Part IV.

Stresses were direct and produced by a periodic motion, about 800 cycles per minute, of a reciprocating mass by means of a connecting rod, the specimen under test forming the link between the reciprocating mass and the cross-head.

The ratio of tension to compression was: for Items 1 to 18, 1.4; for Items 19 to 22, 1.09; for Items 23 and 24, 0.92; for Items 25 to 27, 0.72.

Item 19 was one of a set which the authors believed to be subject to some secondary effect, to avoid which they made test pieces somewhat smaller for set including Items 20 to 22.

All stresses are in tons per square inch.

Materials used in experiments.	Chemical Analyses.					Tension Tests.		
	Percentages of:							
	C.	Mn.	Si.	S.	P.	Primitive elastic limit.	Maximum load.	Total elongation in 8 in. Percentage.
Swedish Bessemer Steel No. 3	0.645	0.260	0.062	0.010	0.028	27.66	47.60	12.9
Swedish Bessemer Steel No. 2	0.446	0.370	0.058	0.012	0.028	25.00	43.75	17.0
Swedish Bessemer Steel No. 1	0.170	0.100	0.021	0.012	0.013	21.42	28.53	22.8
Piston-rod steel	0.446	0.470	0.063	0.044	0.067	19.62	43.85	18.1
Steel forging	0.336	0.560	0.072	0.021	0.026	12.94	29.47	16.6
Mild steel No. 2	0.331	0.680	0.086	0.056	0.066	14.30	28.30	24.6
" " No. 1	0.065	0.040	0.148	0.010	0.135	10.72	21.92	28.0
Swedish charcoal iron	0.039	Trace	Trace	0.000	0.018	12.93	19.60	33.8
Wrought iron No. 2	0.195	0.005	0.086	0.011	0.054	13.37	25.58	23.8
" " No. 1	0.029	0.070	0.127	0.024	0.219	14.28	23.76	27.0

TABLE 4.—(*Continued.*)

Item.	Material.	Maximum tension.	Maximum compression.	Maximum range of stress.	Ratio of tension to elastic limit.	Ratio of range of stress to elastic limit.	Number of reversals.	Result of test on specimen.
1..	Swedish Bessemer Steel No. 3.	18.95	13.54	32.49	0.685	1.175	204 000	Broken.
2..	do. No. 3.	18.28	13.05	31.33	0.661	1.133	1 561 000	Not broken.
3..	do. No. 2.	17.60	12.57	30.17	0.704	1.207	129 500	Broken.
4..	do. No. 2	16.97	12.13	29.10	0.679	1.164	1 287 000	Not broken.
5..	do. No. 1.	15.63	11.17	26.80	0.730	1.251	1 001 000	Broken.
6..	do. No. 1.	14.96	10.69	25.65	0.698	1.197	2 148 000	Not broken.
7..	Piston Rod Steel.............	16.80	12.00	28.80	0.856	1.468	752 000	Broken.
8..	do.	16.26	11.62	27.88	0.829	1.421	3 409 000	Not broken.
9..	Steel Forging.................	12.31	8.79	21.10	0.951	1.631	386 300	Broken.
10..	do.	11.14	7.95	19.09	0.861	1.475	1 782 800	Not broken.
11..	Mild Steel No. 2...............	15.00	10.71	25.71	1.049	1.798	1 330 000	Broken.
12..	do. No. 2...............	13.59	9.70	23.29	0.950	1.629	2 000 000	Not broken.
13..	Mild Steel No. 1...............	11.05	7.90	18.95	1.031	1.768	1 055 300	Broken.
14..	Swedish Charcoal Iron........	11.17	7.98	19.15	0.864	1.481	693 500	Broken.
15..	do.	10.77	7.70	18.47	0.833	1.428	1 360 000	Not broken.
16..	Wrought Iron No. 1......	12.39	8.85	21.24	0.868	1.487	214 900	Broken.
17..	do. No. 1...........	11.78	8.42	20.20	0.825	1.415	1 116 300	Not broken.
18..	do. No. 2...........	11.26	8.04	19.30	0.842	1.444	904 800	Broken.
19..	Wrought Iron No. 2...........	9.28	8.51	17.79	0.694	1.331	942 000	Broken.
20..	Swedish Charcoal Iron	10.37	9.51	19.88	0.802	1.538	271 800	Broken.
21 .	do.	9.86	9.04	18.90	0.763	1.462	1 345 000	Not broken.
22..	Wrought Iron No. 2...........	10.09	9.26	19.35	0.755	1.447	1 045 000	Not broken.
					Compression to elastic limit.			
23..	Swedish Charcoal Iron.......	9.06	9.84	18.90	0.838	1.462	486 600	Broken.
24..	do.	8.46	9.19	17.65	0.711	1.365	1 029 800	Not broken.
25..	do.	7.69	10.69	18.38	0.827	1.422	523 500	Broken.
26..	do.	7.36	10.22	17.58	0.790	1.360	1 004 000	Not broken.
27..	Wrought Iron No. 2....	8.10	11.25	19.35	0.841	1.447	1 045 000	Not broken.

members, however, as the frequency of the alternations is much less than in these tests, and as periods of rest are interspersed between alternations, it is fair to assume that the limits between which the stresses can alternate are greater than in the tests. It is a fair inference from the tests cited that stress of great intensity in tension or compression reduces the capacity of a structural member to resist immediately, without injury, stress of the opposite kind, but not to the extent indicated in Tables 3 and 4.

In the case of a member subject to alternate tension and compression of equal intensity, if the capacity of the steel to resist either stress were reduced to two-thirds of what it would be to resist one or the other without any alternations, the effect on the sectional area required would be equivalent to that of a 50% increase in the total stress in a member subject to only one kind of stress; and the ratio of the range of stress (that is, tension plus compression) to the capacity of the metal when there are no alternations of stress to resist without injury either kind, would be twice two-thirds or 1.333. When this ratio is compared with the ratios of range of stress to elastic limit given in Table 4, in the light of the differences in conditions, the assumption from which it was derived seems reasonably safe. The proportion chosen for this tentative assumption was such as gives, when the alternate stresses are equal, some basis of comparison of Table 4 with the provision for alternating stresses given in the American Railway Engineering Association's General Specifications for Steel Railway Bridges. This provision, taken from the third edition (1910), Paragraph 22, is as follows:

"Members subject to alternate stresses of tension and compression shall be proportioned for the stresses giving the largest section. If the alternate stresses occur in succession during the passage of one train, as in stiff counters, each stress shall be increased by 50 per cent. of the smaller. The connections shall in all cases be proportioned for the sum of the stresses."

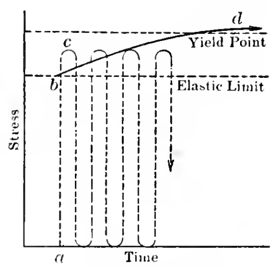
In certain conditions, some of the fatigue under alternating stresses within the elastic limit is temporary. Lord Kelvin and other experimenters have observed such a fatigue in vibrating wires. Wires which had been kept vibrating for several hours or days, within certain limits much below the elastic limit, came to a rest much sooner when left to themselves than when set in vibration after they had been at rest for several days and were then immediately left to themselves. This may have been due to initial internal stresses which, in combination with stresses from the external forces, overstrained small portions of the metal and made them viscous. The rapid vibration of the wires may then have prevented the viscous metal from solidifying, and gradually increased the fatigue. During a rest, the viscous portion of the metal would resolidify, and new internal stresses would be developed, as previously explained in discussing flexure.

It is a matter of experience that, when there are bad faults in steel or wrought iron, failure may occur under stresses (which are repeated or continued) of computed intensity less than the elastic limit, with little prior warning in the way of deformation. It is conceivable that failure of steel and wrought iron from fatigue might similarly occur under repeated or continued stresses within the elastic limit, even when the initial flaws are microscopic; but there is nothing in experience or tests to cause fear of such a result when the material is of good quality and the stresses are not reversed. Of course, failure may occur in compression from slenderness under stresses within the elastic limit, but this has nothing to do with fatigue.

The most thorough, scientific, and valuable experimental investigation of repeated stresses in steel and wrought iron was made by the late Professor Johann Bauschinger. In these experiments he used a remarkable measuring device which was sensitive to $\frac{1}{10\,000}$ mm. (about $\frac{1}{250\,000}$ in.), and the repetitions of stress ranged from 5 000 000 to 10 000 000, or more.

The results of this profound investigation by this noted scientist were published in 1886,* and were well epitomized by Professor W. C. Unwin in discussing Stanton and Bairstow's paper on reversals of stress, as follows:

"Bauschinger was the first to notice the remarkable variation of the position of the true limit of elasticity—not the yield-point, but the limit of proportionality—when a bar was subjected to straining actions. The important Paper which he wrote in 1885 dealt almost wholly with the effect of variations of tensile stress, and the point which Bauschinger fully made out was illustrated diagrammatically by Fig. 38.† Suppose a bar subjected to a stress varying between 0 and a limit *c* above the real primitive elastic limit. The successive applications of the stress were shown by the dotted line. The elastic limit initially at *b* would rise sometimes above the primitive yield-point as shown by the strong line *b d*. Now if *d* was above the applied stress *c*, no number of repetitions of stress would break the bar. But if *c* was above *d*, the point to which the elastic limit rose, then the bar would break after a certain number of repetitions of stress. That was for variation of stress in one direction, and he thought it was something more than a mere theory, and that the point had been completely made out."



(Unwin's Fig. 38)
FIG. 6.

It is evident that when the stresses are not reversed the elastic limit of steel and wrought iron in structures is the criterion of safety with respect to stress intensity, and that the real factor of safety in

* Communication No. 13, Testing Laboratory, School of Technology of Munich.
† Reproduced herein as Fig. 6.

such cases is the ratio of the elastic limit to the actual stress, instead of the ratio of the momentary ultimate strength to the actual stress.

For steel and wrought-iron railway bridges, when the actual stresses in members subjected to only one kind of stress are within the elastic limit, and when the actual stresses in members subjected to alternate stresses are within two-thirds of said limit, it is reasonable to assume that the life of these structures will depend on other considerations. Although experiments do not warrant the conclusion that steel and wrought iron can resist endless repetitions of stress to those limits, neither do they warrant the conclusion that these metals cannot do so; and both experiments and experience indicate that steel and wrought iron in bridges can resist to these limits for so long a period that the resistance may for practical purposes be considered permanent. This, of course, does not mean that a structure is necessarily safe if the computed stresses are within the supposed elastic limit (or two-thirds thereof if the stress alternates); for the real stresses may be greater than computed and the actual elastic limit less than supposed, and the compression members may be lacking in stiffness and the structure unstable.

The fatigue or weakening of a piece of steel or wrought iron which occurs when it is strained in tension and compression alternately beyond certain limits (which are often well within the elastic limit) makes it subject to sudden fracture, without much preliminary deformation; similarly, as in a piece in which the crystals or grains have united in regular crystalline formation without much mechanical interference from hot-forging, rolling, or pressing; hence such weakening is often called crystallizing, and by some is actually conceived to be a phenomenon in crystallogeny—an idea fostered by the fact that the crystals or grains of which steel and wrought iron are composed are displayed in sudden fractures but are more or less disguised in ordinary tests for quality by being drawn out before they are broken.

There is probably no change, in the structure of metals, from strain, so long as no part is over-strained. When metals are made partly viscous by over-straining and are then allowed to resolidify, the resolidified portion, of course, has a new structure. In lead, according to Ewing, severe over-straining is followed, even at atmospheric temperatures, by a protracted crystalline growth which results in the formation of crystals which are relatively very large.* There is no evidence, however, that steel and wrought iron made viscous by over-straining resolidify in large crystals at atmospheric temperatures. Atmospheric temperatures are so far below the recalescence point of steel and iron that it seems reasonable to expect that the viscous metal at such temperatures will not resolidify in large crystals. There is, in fact, considerable to indicate that films of steel made viscous by over-straining will, after resolidification, be in an amorphous condition; that is, not crystallized, even in the minutest particles. It would seem that the solidification is, in the main, so rapid that the crystals do not have time in which to grow to discernible size.†

Launhardt's Fatigue Formula.

As has been shown, the elastic limit of structural steel and wrought iron can be raised by over-straining followed by a rest. Experiments by Wöhler during the period 1860–1870 indicate that it can also be raised when part of the stress is constant and part is constantly repeated, even without intervals of rest, and seem to indicate that the amount by which it can be raised increases with the proportion of constant stress. The phrase "seem to indicate" is used deliberately,

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* Encyclopædia Britannica, 11th Ed., Vol. XXV, p. 1018.

† "About ten years ago [dating from May, 1911] the microscopic study of the structure and behavior of metal led to the discovery of the true nature of the operation of polishing. In this operation a true skin is formed over the polished surface. This skin gives unmistakable signs that it has passed through a state in which it must have possessed the perfect mobility of a liquid. In its final state it possesses distinctive qualities which differentiate its substance very clearly from that of the unaltered substance beneath it. It is, for instance, much harder and, even when formed on the face of a crystal on which the hardness varies in different directions, its hardness is the same in all directions. * * * The discovery that layers of a solid many hundreds of molecules in thickness can have a mobility of the liquid state conferred on them by purely mechanical movement, opened up a new field of inquiry into internal structure of metals which have been hardened by cold working. As a result of this inquiry a theory of the hard and soft states was suggested. According to this theory, hardening results from the formation at all the internal surfaces of slip or shear of mobile layers similar to those produced on the outer surface by polishing. These layers only retain their mobility for a very brief period and then solidify in a vitreous amorphous state, thus cementing material at all surfaces of slip or shear throughout the mass. * * *

"The ductile metals, when pure, do not pass into a vitreous amorphous state by cooling, because their molecules retain the power of crystalline rearrangement over a very long range of temperature below the solidifying point. Gold solidifies at 1080° and its minimum crystallizing temperature is somewhere about 230°. There is thus a range of about 800° over which crystallization can occur. It is obvious that no ordinary method of chilling could carry a mass of metal over this long range so quickly that it could not crystallize. Though the arrest of crystallization by chilling the molten metal is practically impossible, this arrest can and does occur in the thin layers of mobile molecules which are produced by mechanical flow. The evidence from observations which have extended over nearly ten years has made it certain that metals can exist in the vitreous amorphous form, and that the recrystallization which occurs when the point of thermal instability is reached is strictly analogous to the similar phenomenon which occurs when other well-known vitreous substances are kept at a suitable temperature in the presence of crystalline nucleus." From "1911 May Lecture", by G. T. Beilby, LL.D., F. R. S. (Member of Council) on "The Hard and Soft State in Metals", published in the *Journal* of the Institute of Metals, Vol. VI, pp. 5, 6, and 9.

for the reasons that the experiments in which the stress was produced by direct pull were meager and inconclusive, and the nominal stresses recorded in the extensive bending tests were computed by the ordinary theory of flexure, which is not even approximately correct when the elastic limit is exceeded.

Following Wöhler's experiments, Launhardt devised what is known as a fatigue formula, which is supposed to indicate the farthest point to which the stresses can be carried just to avoid failures from fatigue under various proportions of constant and constantly repeated stresses.

Launhardt's formula, as given by Weyrauch for wrought iron, is

$$a = u\left(1 + \frac{1}{2}\,\frac{\text{Minimum stress}}{\text{Maximum stress}}\right) \ldots\ldots\ldots\ldots\ldots (1)$$

where

a = ultimate working strength per unit of section under the conditions assumed,

u = ultimate strength per unit of section for any number of repetitions of load.

In Wöhler's tests, a bar repeatedly pulled from 0 to 320 centners per square zoll, finally ruptured on the 10 141 645th application of the stress.

320 centners per square zoll is a little more than 30 000 lb. per sq. in.*

Adopting the square inch and the pound as units, and taking the value of u as 30 000, the Weyrauch-Launhardt formula for wrought iron becomes:

$$a = 30\,000\left(1 + \frac{1}{2}\,\frac{\text{Minimum stress}}{\text{Maximum stress}}\right) \ldots\ldots\ldots\ldots (2)$$

According to this formula, the greatest stress per square inch to which wrought iron can be subjected without permanent fatigue varies from 30 000 lb., in cases where all the stress is constantly repeated, to 45 000 lb., in cases where it is all constant.

As even 30 000 lb. is above the elastic limit of ordinary wrought iron, such metal would have to have its elastic limit raised somewhat more than 50% by over-straining before it could stand permanently 45 000 lb. per sq. in.

It is not reasonable to apply this and similar formulas to the design of bridges, because two of the fundamental considerations on which such formulas rest are not realized in these structures: the

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* According to Bauschinger (*loc. cit.*, p. 44), the centner per square zoll in which Wöhler gives his results in equivalent to 6.837 kg. per sq. cm., or 972 lb. per sq. in.

stresses are not constantly repeated without intervals of rest; and the permanent strength cannot possibly be increased, in non-adjustable tension and compression members, far above the primitive elastic limit, for the reason that the change in length of such members when strained beyond the yield point is so great as to be ruinous. After once being strained a little beyond the yield point, there would be no repeated stresses. It is quite probable, however, that, at the expense of some undesirable though not ruinous distortion of a structure, its tension members and very short compression members could have their elastic limit and practically permanent strength raised nearly to the yield point.

A considerable number of American engineers use a formula, in appearance greatly resembling Launhardt's, which evaluates the permissible working stress per square inch with quantities intended to give a constant factor of safety, with respect to the capacity of the metal just to avoid permanent fatigue, and at the same time allow for impact. As an illustration, the following formula is quoted, from the specifications of a large railway system, for permissible tension per square inch.

$$\text{Tension, rolled bars,} = 7\,500 \left(1 + \frac{\text{Minimum stress}}{\text{Maximum stress}}\right) \ldots\ldots(3)$$

In explaining this formula, the capacity of the metal just to avoid permanent fatigue is assumed to be a function of the maximum permissible stress (from 7 500 to 15 000 lb. per sq. in.), instead of a function of the maximum permanent strength (from 30 000 to 45 000 lb. per sq. in., according to the minimum); a modification for which, as far as the experiments or theories regarding fatigue are concerned, there is no warrant.

Some engineers, who realize that Formula (3) is wholly unsound with respect to the possibilities of fatigue in bridges, continue to use it, on the ground that it makes a good provision for impact. Those who advocate it solely as a provision for impact should use an equivalent method of making such provision, which clearly defines their position, is much more convenient, and brings precisely the same sectional area, as follows:

$$\text{Impact} = \text{live load} \left(\frac{\text{Maximum stress}}{\text{Maximum stress} + \text{minimum stress}}\right) \ldots(4)$$

Permissible tension in rolled bars = 15 000 lb. per sq. in.

The chief objection to formulas such as (3) and (4) is that, for long-span bridges, they make the provision for dead load relatively too small as compared with the provision for live load; which may be dangerous when the permissible unit stress is high and the dead load predominates.

In the case of bending stresses, either by themselves or in combination with direct tension or compression, there is some opportunity for enhancement of the elastic limit, without serious distortion, under constant stresses or repeated stresses in one direction, especially in solid members such as pins; but, in the case of bending stresses in combination with direct compression, the opportunity is quite limited.

Acknowledgment is made of valuable suggestions from E. C. Chase, Jun. Am. Soc. C. E., who kindly made a critical review of the paper in its preliminary form.

AMERICAN SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

WATER SUPPLY OF THE SAN FRANCISCO-OAKLAND METROPOLITAN DISTRICT

Discussion.*

By Messrs. A. Griffin, J. Horace McFarland, F. C. Herrmann, Walter Hy. Brown, and H. T. Cory.†

A. Griffin,‡ Assoc. M. Am. Soc. C. E. (by letter).—One who has followed the efforts of San Francisco's representatives to secure the Hetch Hetchy water supply for San Francisco, and who has read the papers and talked with the residents of San Francisco, cannot have failed to observe the lack of a grasp of the true situation. This observation applies with almost equal force to the engineer and to the layman, and the silence of the San Francisco press on every subject in the least degree unfavorable to the Hetch Hetchy project is very surprising. Mr. Griffin.

It would seem that, in planning a great municipal water supply, at a cost of $50 000 000, the adequacy of the source should be ample, even to excess, and that the engineering and legal advisers of the project should report adversely unless the source is shown to be ample under the most unfavorable assumptions. Yet we have the peculiar spectacle of the Hetch Hetchy burden being laid on the taxpayers of San Francisco, supported by unsafe assumptions, by half statements of facts, and by absolute silence on all unfavorable features, when it is known, beyond the possibility of a doubt, that the works cannot be supplied to capacity during critical periods which recur with moderate frequency. This is made known even by computations based on as-

* Discussion of the paper by H. T. Cory, M. Am. Soc. C. E., continued from November, 1915, *Proceedings*.

† Author's closure.

‡ Manteca, Cal.

Mr. Griffin. sumptions as to storage capacity and irrigation use which are calculated to show the greatest possible quantity available for a municipal supply.

There is actually no definite and conclusive knowledge as to the quantity of water land requires, nor what represents the most efficient use, nor what represents the greatest beneficial use to any person or community, which last is the quantity for which the Modesto and Turlock Districts can rightfully contend. These quantities, in fact, are variable from year to year, depending on the crops, rainfall, prices, and many other factors. The computations which show 400 000 000 gal. daily available for San Francisco are based on an assumption as to the annual use in irrigation, which might easily be 50% greater, and, if it were 20% greater, the quantity shown by the computations would be wholly inadequate, not to mention the fact that, if the assumptions as to the monthly use of water and the quantity of storage available had been more conservative and more in accord with the probable facts, the quantity shown as available for San Francisco would have been decreased still further.

The danger of assuming too small a water requirement for land is illustrated forcibly by the history of the Reclamation Service. The original assumptions led to the making of contracts with settlers to deliver from 1½ to 3 acre-ft. per acre per annum to the land. In many instances it has been found necessary to modify these contracts, if not legally, by common consent; and on some of the projects the United States Reclamation Service is actually delivering 10 and even 20 acre-ft. per acre per annum to some of the lands, and the officials in charge of operation consider these quantities necessary for the best agricultural results. Although extreme conditions are represented by such uses, the general testimony of officials of the Reclamation Service is that it was necessary to revise the first assumptions as to the water requirement of irrigated lands in favor of the use of a greater quantity.

A feature which has been brought forcibly to the writer's attention at various times while engaged in irrigation operations is that the years of deficient run-off are accompanied by deficient winter and spring rainfall in the adjoining irrigated areas; therefore, there is an earlier, a longer, and a greater demand for water for irrigation; that the total quantity used is increased over that used under normal conditions; and that the seasonal distribution of this use is altered.

It has also been assumed that the Modesto and Turlock Irrigation Districts will develop foot-hill storage to the maximum capacity of the basins tributary to their canals, though, as a matter of fact, it is doubtful whether it will ever be economically feasible to develop them to much more than half this maximum, due to the increasing values of the sites for agricultural purposes and the uncertainty of filling the basins through their two diverting canals.

Mr. Griffin.

Aside from the probability of the actual failure of San Francisco to get the desired supply from the Tuolumne, the consequent loss from lack of water, and a partial use, only, of an enormous investment, and the possibility of having to duplicate the investment to secure an additional supply from another source, there should be considered the case of the lands outside the Modesto and Turlock Districts which are dependent on the Tuolumne for a water supply. According to the report on the Irrigation Resources of California, by Mr. Frank Adams,* there are 450 000 acres of valley and plains land tributary to the Tuolumne, and an additional area of foot-hill land between the Stanislaus and the Merced Rivers of 180 000 acres, of which it may be assumed that one-half, or 90 000 acres, is tributary to the Tuolumne, making a total of 540 000 acres tributary to that stream. From personal familiarity with these lands the writer knows that practically all of them are susceptible of being irrigated beneficially; but it is a fact that economic conditions do not warrant the expenditure of the money necessary to provide them with a water supply to-day, and may not warrant this expenditure for years to come. The possibilities of development are there, however, and can never be realized until water is applied to them; and, if the Hetch Hetchy project is carried to a conclusion, most of them can never receive water. This is rendered the more certain on account of the proposed development of so many of the reservoir sites of the Tuolumne for municipal supply. The lands yet to be supplied with water will have inferior water rights, and will be much more dependent on storage than the Modesto and Turlock Districts. The control of 1 acre-ft. of stored water for late irrigation would make possible the use of from 1 to 3 acre-ft. of natural flow for irrigation of the same land in the spring and early summer; but, with the proposed depletion of the total supply of water in the river and the utilization of the best reservoir sites for the San Francisco supply, there would only be left the inferior and expensive reservoir sites and the peaks of the floods for the latter lands, with the probability of no water supply at all in critical periods. This would make any development beyond that at present inaugurated impossible, from an economic standpoint.

The report mentioned previously shows that the San Joaquin Valley has an area of irrigable or agricultural land of more than 8 000 000 acres, with a mean annual run-off of about 11 000 000 acre-ft. and a minimum run-off of about 5 000 000 acre-ft., and that the Sacramento Valley has a similar area of somewhat more than 4 000 000 acres with a mean annual run-off of 26 000 000 acre-ft. and a minimum run-off exceeding 12 000 000 acre-ft., and with a much higher annual precipitation over the agricultural lands. One cannot help being im-

* Issued as a State Report in 1912, and also issued by the Department of Agriculture as O. E. S. *Bulletin 254*.

Mr. Griffin. pressed with these figures, and, knowing that water can be taken to San Francisco from the Sacramento Valley at a cost not greatly different from that of the Hetch Hetchy project, with an absolute assurance of its adequacy, one wonders at the persistent partisanship of the people who have led San Francisco into the Hetch Hetchy scheme.

It would seem that, if only for the selfish reason of permitting a tributary community to develop to its highest in order to increase its buying and selling capacity, San Francisco might well keep out of the San Joaquin Valley. Aside from the actual loss that will accrue through arrested development, there is a growing personal antagonism to San Francisco on the part of many people of the San Joaquin Valley, and this has already diverted trade from San Francisco to other centers; and, as time goes on and it is seen more clearly how this enterprise has stifled development, and when, during critical periods, San Francisco shall become involved in altercations and legal controversies with the irrigation interests over the division of water, this feeling will be greatly intensified. Even to-day the Modesto and Turlock Districts, which can be injured very little if the terms of the Raker bill are adhered to, have filed suits against San Francisco, and from time to time are making strategic legal moves for the purpose of checkmating her wherever possible.

Mr. McFarland. J. Horace McFarland,* Esq. (by letter).—After several years of more or less close connection with the so-called Hetch Hetchy project for the water supply of San Francisco and its appurtenant communities, the writer has a natural interest in this paper.

The position of the American Civic Association, in this matter, is as follows: Those who make up that Association are a unit in the position that no use of water is so important and so beneficial as that for domestic purposes, and at no time in the Hetch Hetchy controversy have they lost sight of this basic fact.

They have felt, however, all the time, that before consenting to the virtual destruction and withdrawal from a possible very beneficent use of a unique and unreplaceable portion of the world's surface, absolute necessity should be shown.

Before committees of Congress, before successive Secretaries of the Interior, and, at various times, the writer has contended, first, for the absolute necessity of the best possible domestic water supply for any city; and, second, for that fair and impartial investigation as to various sources of supply which he is constrained to believe, even now, after following the matter for at least six years, has never yet been made in relation to San Francisco.

Having heard voluminous statements by many engineers, and having read countless pages on the subject, he is still of the opinion

* President, American Civic Association, Harrisburg, Pa.

that the basis of the engineering investigation with respect to the water supply of San Francisco has never been impartial. All the engineers employed by San Francisco and all those called to support their findings have devoted themselves with one voice to exploiting the Hetch Hetchy as the only supply, and to minifying, instead of investigating, other possible sources. Mr. McFarland.

Now, given equal purity and potability, a glass of water from one source is as useful to the residents of any city as a glass of water from another source. Taking into account the turning of the American people toward scenic phenomena and the beginning of a recognition of the magnificent scenery in America to attract visitors, it is, and has been, fair to assume, that any great scenic source of water supply ought to be very thoroughly studied, not with reference to its commercial availability for power and then its incidental availability for a domestic supply, but from the standpoint of being used only as a last resource, after all other economically possible sources have been considered.

The writer does not believe this has ever been done, and as respecting the findings that have been recorded so far in regard to the Hetch Hetchy supply, he is constrained to repeat a remark made in his hearing by a very vigorous ex-President of the United States, referring to a certain Goverment official who was just then terminating a career of actually pernicious activity. He said: "If Mr. B. believes a man to be guilty, he sets out to find evidence to back up his belief. If he doesn't find it, Heaven help the evidence!"

At least three mayors of San Francisco and two succeeding city engineers, together with a dozen other high officials of that enterprising and wonderful city, would testify in the writer's favor that at every hearing where they have met he has reiterated the statement that if the Hetch Hetchy Valley was shown to be the only practicable source of a satisfactory water supply for the City of San Francisco, the American Civic Association would be the very first organization to recommend that it be given up to that city; but San Francisco has never shown this.

The extreme value in promoting and maintaining human efficiency by great recreation places, open to all the people; the great economic value of unmatched and unique scenery to attract travel and, therefore, revenue to the United States from all the world; a decent respect for the unique glories of our own land, and a regard for the findings and opinions of a man so exalted in his attitude and so high in his knowledge as the late John Muir—all unite in promoting the feeling that the present situation of the Hetch Hetchy matter in its relation to the City of San Francisco is working out to a great wrong to that city, to the United States, and to the whole world.

Mr. Herrmann.

F. C. Herrmann,* M. Am. Soc. C. E. (by letter).—The author has taken a very large subject, and, covering it in a broad and general way, has omitted the many interesting engineering features relating to the present water supply system of San Francisco. It is to be regretted that members who have been connected most intimately with the problems of this work and their solutions have not participated in the discussion.

By reason of climatic and topographic conditions in the region of San Francisco, the problems were unique; and, because that city was isolated from other large centers of engineering activity during its development, their solution was independent in character, often resulting in bold engineering, such as the early use of long lines of thin, riveted wrought-iron pipe of large diameter, high earthen and concrete dams, and ashlar masonry dams of the arch and buttress type with slender cross-section.

Early in the history of these works it was found that long cycles of years having less than average run-off were likely to occur, and, to provide against them, copious storage was essential. The rule was formulated that there should always be available storage capacity equivalent at least to the consumption for 1 000 days.

It is to be hoped that the engineering accomplishments of this system will be presented first-hand to the Profession before very long.

In his discussion, Mr. O'Shaughnessy makes unfavorable comment on the character and reliability of the run-off records of the Spring Valley Water Company, as well as the estimates of water crop by a number of engineers, including the writer. It is to be presumed that he means the Alameda system only, for the records of the peninsular system are probably the best and most reliable anywhere in the western part of the United States.

Water-works engineers of wide experience who have had occasion to examine carefully the hydrographic records of the Spring Valley Water Company have stated that they are very much better than is usual with water-works systems. From his own experience, the writer knows that they are far superior to those existing generally in the West and Middle West.

The Alameda system is as yet but slightly developed. There remain to be constructed three reservoirs having an aggregate storage capacity of more than 77 000 000 000 gal., one of which is the Calaveras Reservoir (52 000 000 000 gal.) which is now being built and will be used during the coming season. A number of engineers have made careful estimates of the yield of the Alameda system; others have made statements of yield without careful analysis. The results differ widely, just as they have differed widely in the case of the Tuolumne

* San Francisco, Cal.

River. The wide variation in the estimates of yield of the Alameda system is due in some degree to the use of different fundamental elements, such as storage available and allowances for future local consumption. Mr. Herrmann.

The waste water of the Alameda system (650 sq. miles above Sunol Dam) finds its way into San Francisco Bay through Alameda Creek. Record has been kept of this by measuring the depth of water over the Niles Dam from 1889 to 1900, and over the Sunol Dam from 1900 to date. In times of high flood both these dams act as submerged weirs, with high velocities of approach. The discharge was computed from these depths by the Spring Valley Water Company by using the formulas, $Q = 4\ 200\ b\ h^{\frac{3}{2}}$ for the Niles Dam, and $Q = 4\ 400\ b\ h^{\frac{3}{2}}$ for the Sunol Dam, which was adopted by Hermann F. A. Schussler, M. Am. Soc. C. E., after numerous observations and measurements. Mr. Schussler has always maintained that discharges computed by these formulas were conservative, particularly in stages of high flow.

Unfortunately, the United States Geological Survey published a record of the flow of Alameda Creek over the Niles Dam, which was fragmentary and based on wholly erroneous data, but indicated that this flow was very materially less than is shown by the records of the Spring Valley Water Company.

This was made quite an issue in the investigations of 1912 by the City of San Francisco preparatory to the hearing before Secretary of the Interior Fisher. Those in charge of the City's affairs appointed a committee composed of C. D. Marx, President, Am. Soc. C. E., of Stanford University, Charles Gilman Hyde, M. Am. Soc. C. E., of the University of California, and C. E. Grunsky, M. Am. Soc. C. E., former City Engineer of San Francisco. The duties of this committee were to make an analysis of the discharge of Alameda Creek over the Niles and Sunol Dams, and of Calaveras Creek at the Calaveras Dam site, from the original records of the Company.

These gentlemen, with the necessary assistants, made a very careful and exhaustive examination of the records, and a survey of the stream bed and structures.

The controversy as to the flow of Alameda Creek arose during the period of low-water flow, making it impossible to calibrate the dams by stream measurements prior to the hearing before Secretary Fisher. Messrs. Marx, Hyde, and Grunsky, therefore, made discharge curves for the dams from theoretical analysis.

At the time that these gentlemen began their investigation, Professor J. N. LeConte, of the University of California, conducted a series of experiments for the writer with models of these dams. These models and the approaches to them were exact miniature counterparts

Mr. Herrmann.

of the structures and the stream bed above them as they existed during the times of stream flow observations. Their dimensions were one-twentieth and one-nineteenth of those of Sunol and Niles Dams, respectively. The models were by no means small, having crest lengths of more than 6 ft., and they were calibrated for different rates of flow, from about ½ to 17 sec-ft., and for different degrees of submergence.

Diagrams* were prepared showing the relation of up-stream head to submergence for various values of Q, the discharge curves for the models for different degrees of submergence, the water-surface line at the two dams for the flood of March, 1911, and the arrangement of the experiment station. There was also a diagram of the models.

The flow of water was measured through sharp-edged weirs, using the standard formula, $Q = C \frac{2}{3} \sqrt{2g}\, b\, h^{\frac{3}{2}}$, the coefficient, C, being taken from tables for contracted weirs by the late Hamilton Smith, M. Am. Soc. C. E.

The heads were measured with hook-gauges reading to 0.001 ft., and the degree of submergence was controlled by baffles placed 30 ft. below the models. The conditions were ideal to secure a constant flow for a full set of experiments. The experiments, and the application of their results to the large dams, have been described by Professor LeConte in his report to the writer.

His results were made available to Messrs. Marx, Hyde, and Grunsky before they had finished their analysis. His work, as well as that of Messrs. Marx, Hyde, and Grunsky, was very severely and unjustly criticised by those representing the City of San Francisco at the hearing before Secretary Fisher.

During the winters of 1912-13 and 1913-14 the Sunol Dam was calibrated by careful stream gaugings taken just above it. Independent measurements were taken by the engineers of the City of San Francisco and the engineers of the Spring Valley Water Company; the data taken by both agreed remarkably well up to a gauge height of 8 ft. For gauge heights above that point complete current-meter measurements were impossible because of the high velocity of the water, and satisfactory data were not obtained. However, as the great bulk of the run-off occurs for gauge heights of less than 8 ft., all the current-meter measurements were assembled, and a discharge curve for the Sunol Dam was constructed by the City Engineer of San Francisco. This curve, together with those obtained from the LeConte experiments, the original curve prepared by Mr. Schussler, the Marx, Hyde, and Grunsky computations, and computations by G. G. Anderson, M. Am. Soc. C. E., is shown by Fig. 28. Inspection

* These diagrams are not reproduced herein, but are filed in the Library of the Society where they may be examined by those who are interested.

Mr. Herrman

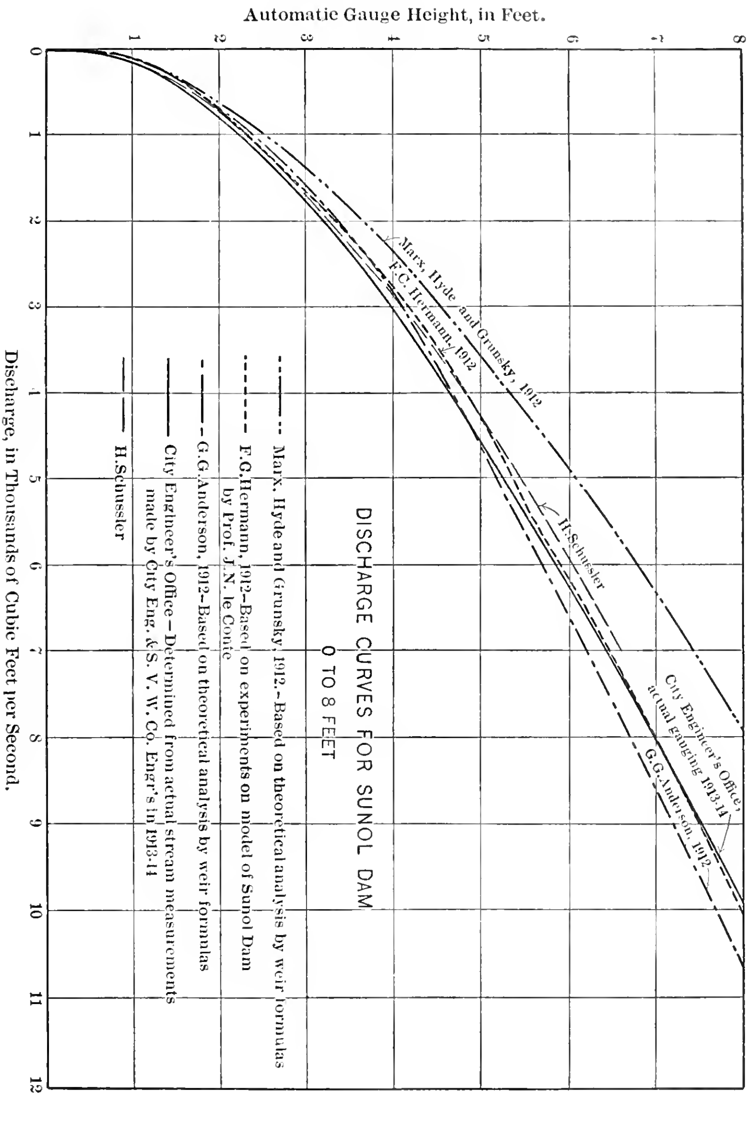

FIG. 28.

Mr. Herrmann. of these shows the very close agreement between the results obtained by the model of the Sunol Dam and by actual stream measurements. Computation of the total flow of Alameda Creek over Sunol Dam from 1900 to 1913, by the curve from actual gaugings, is about 3% in excess of that obtained by the curve constructed from the LeConte experiments on the model of that dam.

Much has been written about the use of water for irrigation from the Tuolumne River by the Turlock-Modesto Irrigation Districts, and computations of their future requirements made by differeut engineers vary between very wide limits. The Modesto Irrigation District feels that it has need for more water than is provided for under the Raker bill, and has brought suit against the City of San Francisco in the California Courts to adjudicate these rights. At the present time it is spending upwards of one-half million dollars to increase the capacity of its main canal, in order that it may divert 2 000 sec-ft. from the Tuolumne River at LaGrange, and is seriously considering the development of large storage at much greater cost, so that it may prolong the irrigation period, and be secure against the critical years of small run-off.

Mr. Brown. WALTER HY. BROWN,* M. AM. SOC. C. E. (by letter).—In this paper, as well as in the many discussions brought out by Mr. Cory's treatment of the problem of the water supply of the so-called, but yet unorganized, San Francisco-Oakland Metropolitan District, there is an evident absence of any definite suggestion as to how the Metropolitan District may best secure an enlarged and adequate water supply from any source other than the Hetch Hetchy region. It is clearly the view of many who have participated in the discussions that the Hetch Hetchy project does not offer the economical possibilities desired, yet the contributions are lacking in any enlightening statements as to where the needed water may be obtained—elsewhere than from the Hetch Hetchy source. Other projects have been suggested, in a tentative way, but Mr. Cory has taken occasion to unfold to view what he considers weak points in the Hetch Hetchy scheme, otherwise known as the Freeman Project, but he does not offer a solution for the difficulties—the impossibilities, if you will—he has discovered.

Mr. Cory has always been painstaking in his professional work, and unusually thorough; and it is to be regretted that in this paper, the result of extensive research and experience in and with the local water problem, he should have criticized, severely yet perhaps with justification, the plans proposed in the Freeman Project, without offering a feasible plan for meeting the water requirements of the cities on the Bay of San Francisco.

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* San Francisco, Cal.

Mr. Rhodin mentions the feasibility of a filtered supply from the San Joaquin or the Sacramento Rivers, also direct draft from the McCloud River, Indian Valley, and Yuba River, as offering possible solutions. Eel River, in the Coast Range Mountains, to the north of San Francisco, is mentioned as an opportunity possessing considerable merit, but no suggestion of the probable cost is offered. Mr. Brown.

Mr. Grunsky refers to the Eel River source in the following sentence:

"The water supply problems to the northward of San Francisco Bay are separate and distinct from those of San Francisco and the East Bay cities, and need not be brought under discussion in connection with the larger San Francisco problem."

The question arises in the writer's mind: Why need it not be brought under consideration and discussion in connection with the larger San Francisco problem? If searched for, there might be reasons for the acceptance of the Eel River source not yet brought to the attention of Mr. Grunsky, or of Mr. Cory who has essayed to expand on the Greater San Francisco water problem, criticising the only source seriously considered, yet neglecting to suggest an alternative.

As a participant in the discussion of this paper, the writer cannot expect, at this date, to go into the engineering and cost details of the Eel River possibilities; but, being familiar with that region for the past seven years, attention is called to the chapter of Mr. Freeman's Report which is devoted to that phase of the situation.

This chapter frankly admits that no study of the Eel River possibilities has been made, and is warrant, in the writer's belief, for some earnest effort being made toward determining the value of the Eel River region as a source of supply for municipal needs. In the first place, it is not necessary, or even desirable, to make the bay crossing under the Golden Gate in the presence of the more favorable crossing offered at McNear Point, near the City of Richmond. San Francisco is not, of necessity, the only objective point in the proposed Metropolitan Water District. Oakland, Alameda, Berkeley, Piedmont, Richmond, and many other thriving cities are expected to contribute toward the construction costs of a new and great water supply, and their interests should be considered in the selection of, as well as in the payments for, a new supply; and, for these combined communities, the Golden Gate route has no part in the problem, under any form of development of the Eel River sources as yet in evidence.

Cost of Initial Development of Eel River Sources.—Construction estimates have been made for an initial development of the Eel River supply for from 12 000 000 to 15 000 000 gal. daily. Peculiar as it may seem, it would not be profitable to bring into the limits of the proposed Municipal Water District, at this time, more than 15 000 000

Mr. Brown. gal. daily, at the outside. The writer was very much surprised when this state of affairs was developed through the analysis of evidence given at a recent hearing before the California Railroad Commission in connection with the East Bay water situation. The reason there is not, at this time, justification for bringing in more than 15 000 000 gal. daily is that the Calaveras Dam is well along under construction, and will provide for all needs of San Francisco proper for the generation now interested in these affairs. The present consumption of the East Bay Cities is somewhat less than 18 000 000 gal. daily, and, with the existing local resources, there is not room for the disposal of more than 15 000 000 gal. daily, which might be secured from a distant source.

Of course, the cost of water per 1 000 gal. to the consumer diminishes with an increased capacity of the supply system, but even so small a quantity as indicated can be delivered into the local storage of the East Bay Cities, at an elevation of 200 ft. above sea level, for less than $5 000 000, gross construction expense, with attending gross operating and overhead charges of less than $1 500 per day. These figures cover the cost of building a pipe line from Eel River, with a capacity of 20 000 000 gal. daily, and would enable the delivery of water to the Bay District for a rate of less than 15 cents per 1 000 gal. The Eel River sources, without storage at points of diversion, by conduit route 130 miles from San Francisco, and utilizing less than the existing terminal storage facilities, will, without question, supply 12 000 000 gal. daily, and, with the storage facilities available at the head-works, at Gravelly Valley, 180 000 000 gal. daily may be depended on as the ultimate safe yield from that particular unit of the Eel River development. When more than 180 000 000 gal. daily are required for the Metropolitan District, there is more water available in the Middle Fork of Eel River, 38 miles north of the South Fork, where an additional supply of 350 000 000 gal. daily may be obtained. This gives a total of 530 000 000 gal. daily from Eel River.

The writer has made extensive studies of the Eel River regions, in connection with work other than the Greater San Francisco water problem, and offers to his associates in the Profession, who are interested in this particular problem, the following notes, subject to further expansion should interest warrant:

1.—The combined Eel River sources are suitable for a programme of gradual and economical development without throwing excessive or undue burdens on any one generation of the communities' inhabitants.

2.—The Eel River sources as here proposed have never, at any time, been investigated by the City authorities, or by the Advisory Board of Army Engineers, as a source of municipal water supply.

3.—By taking a municipal water supply from the Eel River sources, no community interest can, in any way, be threatened or jeopardized by being deprived of water. Litigation, such as threatened in the San Joaquin Valley over established and valuable water rights in connection with the proposed Hetch Hetchy diversion to San Francisco, would thus be obviated. Mr. Brown.

4.—Irrigable lands in the valley of the Russian River, now without irrigation, could be supplied with excess water from the Eel River sources, following the example or policy of Los Angeles in building up and making more productive its adjoining areas.

5.—To leave to the San Joaquin Valley the water available to it, even though the farmer's ideas of his needs may appear extravagant to the man in city life, will result in that community's growth in population and commerce, and actual thrift, which will naturally center in and build up the cities on the Bay of San Francisco.

6.—The region of the Eel River water-shed, above points of diversion, is in its virgin state. Its mountain ranges run from 6 000 to 8 000 ft. above sea. The water therefrom runs free of pollution by habitations; the maximum hardness at periods of lowest water is 17°, French scale; there are no lumber camps or summer resorts on its areas; and the entire water-sheds of both branches of Eel River are enveloped by the Stony Creek National Forest.

7.—Precipitation on large portions of the Eel River region occurs at the rate of 100 in. and more per annum. There are no requirements for irrigation, and all the water in question runs to waste to the sea.

8.—The combination of sources from the Middle Fork of Eel River and the South Fork of the same stream makes a feasible, practicable, commercial project that should receive, at least, the attention of those seriously concerned in the San Francisco-Oakland Municipal Water District problems.

H. T. Cory,* M. Am. Soc. C. E. (by letter).—The writer's purpose in preparing the paper was, first, to acquaint the members of the Society with the general local water situation, and second, to present the subject for discussion by technically trained men before a technically trained audience. Mr. Cory.

The writer, therefore, is not only much gratified with the interest shown by the volume of the resulting discussion, but also that those who have participated include the present City Engineer of San Francisco; the ex-City Engineer who originally suggested the Hetch Hetchy source of supply and outlined the first Tuolumne project; two of the three engineers who have been called into consultation with respect to power features of the present Hetch Hetchy project, and four others who have been employed by the City during the preparation of the

* San Francisco, Cal.

Mr. Cory. Freeman Report and the water-rate cases now pending on the San Francisco side of the Bay; the engineer in charge of preparing the Army Board Report; a member of the Commission which reported to Secretary Ballinger in 1910 on the need of the Hetch Hetchy Valley; the Chief Engineers of the Modesto, the Oakdale, and the South San Joaquin Irrigation Districts; and the President of the American Civic Association.

Analysis of the various comments shows that no one has criticized the writer's conclusions regarding the following:

1.—The future population curves of the San Francisco-Oakland Metropolitan District as a whole and of the several individual sections thereof;

2.—The future water requirement curves of the district and of the several different sections comprising it;

3.—The relative bonded debt, municipal construction needs, and amount of taxable property in San Francisco and Los Angeles now and in the future;

4.—The fact that the problem of a distant water supply is far more real to the East Bay Cities than to San Francisco;

5.—The fact that the East Bay Cities, particularly, should endeavor to get water costing the consumer little if anything in excess of 15 cents per 1 000 gal., and regard such cost limit as of prime importance;

6.—The essential factors affecting the selection of a distant water supply source;

7.—The advantages and disadvantages of various distant water supply possibilities—with the exception of the Hetch Hetchy and Eel River;

8.—The fact that the Sacramento Valley has an excess of water and could easily spare all of San Francisco's needs both present and future; and that the San Joaquin Valley has a deficiency of water for its own needs, no matter to what extent conserved;

9.—The desirability of a water board to handle all water supply problems, which board should be entirely separate and distinct from any and all other municipal authorities.

It is realized, of course, that lack of criticism does not necessarily imply universal approval.

With the single exception of the present City Engineer, Mr. O'Shaughnessy, there have been no expressions of approval concerning the wisdom of San Francisco in building the Hetch Hetchy project, as determined by the provisions of the Raker Bill. Mr. Galloway, states that he is, and has been since the Grunsky proposal of the Tuolumne source in 1902, an advocate of Sierra water, and Mr.

Hammatt feels that the City has gone so far in the matter that discussions of the Hetch Hetchy project are out of place. All other comments which touch on this phase of the subject are either condemnatory or doubtful. Mr. Cory.

The City Engineer alone takes issue with the statements made concerning the yield of the present water sources when fully developed.

Considerable diversity of opinion was expressed concerning the water needs of 300 000 acres of land in the Turlock and Modesto Irrigation Districts.

The discussion has been so voluminous that it is impracticable to summarize the views of those taking part, or, generally speaking, even comment on the various points brought out. As a matter of fact, there is no reason to do so, for, by a careful reading of all the discussions, one can very easily decide the proper weight to be given the various expressions of opinion.

An exception is the discussion by Mr. O'Shaughnessy, which requires some comment. He points out that the writer was in error in stating that San Francisco had more than 2 200 saloons, and that the official figures are 2 051. The writer is glad to be corrected, and will only say in explanation that the figure used, which was taken from the Assessor's records, through misinterpretation of the data, included more than 200 one-day licenses. Neither of these figures quite tells the story, because of the "corner grocery", as the U. S. Revenue Retailers licenses issued during the quarter ending June 30th, 1914, were 5 818, or about 1 in 85 of population.

He also notes that the population curves in Fig. 2 are not identical with those given out by the Census Bureau for the respective metropolitan districts. In the paper the writer was careful to state that "Greater San Francisco-Oakland" and "Greater Los Angeles", as used throughout the paper, comprise, respectively, all the territory which should logically join in a common water supply within circles of 30 miles radius. The populations in these districts are naturally not identical with those found by the Census Bureau for districts with different boundaries, although, as a matter of fact, the differences are quite small.

He also corrects the writer's figure, "about 100 miles of steel pipe", in the Freeman-Hetch Hetchy project, and states that there are 87 miles. The writer was under the impression that more than 13 miles of the pipe line was a double line, but is glad to be put aright.

Regarding the planning and construction of the Municipal Street Railway system and other City work by Mr. O'Shaughnessy, the writer is very glad of this opportunity to express his unqualified admiration therefor. All of such work has been planned along broad lines, of high character, aggressively prosecuted, and carried through without the slightest hint of favoritism or political meddling.

Mr. Cory. In spite of the writer's statement relative to Table 1, showing the estimated yield of various Spring Valley water sources, Mr. O'Shaughnessy comments as though the paper had not emphasized sufficiently the differences of opinion of the various engineers who have investigated the matter. Mr. O'Shaughnessy has stated:

"For years there has been much investigation as to both the ultimate and the available yield of the Spring Valley sources. Many reports and estimates have been filed by various parties—some representing San Francisco or the East Bay Cities, or both; others working in the interests of one or more of the water companies supplying those cities. In matters of this sort it usually happens that investigators of the latter class are very optimistic in their estimates, and those of the former class are more conservative."

A very important method of examining and comparing safe water yields with given storage capacities has been presented in a paper* by Allen Hazen, M. Am. Soc. C. E. In that paper, Figs. 40 and 41 give the curves for California conditions for 95% and 98% dry years, respectively. Throughout much of California the evaporation is in excess of the rainfall, and in the southern part of the State, particularly, the extent of over-year storage required is extraordinarily large on account of the run-off conditions shown in Fig. 17. From the safe yield, read off from Mr. Hazen's Figs. 40 and 41, excess of evaporation losses must be deducted—treated as a part of the draft. The correction ranges from nothing in the Sierras and Upper Coast Ranges to 5% in the Bay region and 25%† in the vicinity of San Diego.

Mr. Hazen's method makes very simple the estimation of safe yield throughout the various parts of the State, and is on the same basis with respect to severity of the drought conditions provided against. That is to say, years are considered as types—no one actual year being taken—and are designated or defined, so far as degree of dryness is concerned, by their position in order of dryness. For example, a year of such a degree of dryness that 95% of the years are wetter—have larger quantities of run-off—and 5% are dryer, is called a 95% dry year; similarly, a year of which it is true that 98% of the years are wetter and 2% are dryer, is called a 98% dry year.

Thus, a 95% dry year standard means that there will be a water shortage in 1 year in 20, and, with a 98% dry year standard, shortage will occur only in 1 year in 50. Table 9 shows the length of the run-off record, mean run-off in acre-feet, coefficient of variation, and available storage, in acre-feet, of several streams, including the important ones mentioned in the paper and in the discussions. These data were used in connection with Mr. Hazen's Figs. 40 and 41, the

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* *Transactions*, Vol. LXXVII (1914), pp. 1539 to 1669.

† Based on 52 in. mean annual evaporation from water surfaces. The California Railroad Commission uses a larger figure.

corrections for excess of evaporation have been applied, and the resulting net yield is given in Table 10 under the headings "95% dry year" and "98% dry year". Mr. Cory.

TABLE 9.

Stream.	Record.	Mean run-off, in acre-feet.	Coefficient of variation.	Available storage, in acre-feet.
Tuolumne River	19 seasons	2 095 000	0.410	1 000 000 / 1 500 000 / 1 800 000
San Leandro Creek	36 seasons	18 164	0.676	14 858
Eel River	9 seasons	552 000	0.473	215 000
Temescal Creek	9 seasons	1 162	0.663	460
Calaveras Creek	16 seasons	50 400	0.605	162 700
Upper Alameda		15 700		
Total		66 100		
Crystal Springs System	25 seasons	20 700*	0.610	92 070
Boulder Creek / Lake Cuyamaca	26 seasons	4 550	0.721	11 000
San Luis Rey River at Warner's	18 seasons	20 920	1.011	162 000
Cottonwood Creek at Barrett	9 seasons	20 479	0.830	73 675
Cottonwood Creek at Morena Dam	7 seasons	8 150	0.816	46 000
Otay Creek	7 calendar years	5 610	0.474	43 250
Sweetwater	Last 7 seasons	10 007	0.813	
Sweetwater	26 seasons	11 450	1.387	
Cottonwood Creek at Barrett	26 seasons	19 000†	1.350	73 675
Cottonwood Creek at Morena	26 seasons	9 200†	1.000	46 000
Otay	26 seasons	6 310†	1.350	43 250

* Net—that is, it does not include quantity lost by evaporation from reservoirs.
† Most probable values for long record—see Fig. 17.

TABLE 10.

Source.	95% dry year.	98% dry year.	Railroad Commission.	O'Shaughnessy.
Tuolumne:	Acre-feet.	Acre-feet.		
1 000 000 acre-ft. storage	1 066 000	943 000		
1 500 000 " " "	1 275 000	1 173 000		
1 800 000 " " "	1 380 000	1 275 000		
	Millions of gallons daily.	Millions of gallons daily.	Millions of gallons daily.	Millions of gallons daily.
Eel	180			
San Leandro	6.65	5.14	6	
Temescal	0.266	0.198	0.250	
Crystal Springs	18.5	17.0		
Calaveras	43.24	41.5		Less than 30
San Luis Rey	12.8	12.2		13
Otay	3.1	2.74	2.5	5.16
Morena	4.6	3.86	3.5	8.5 in 1912 / 6.5 " 1913
Cottonwood: Morena, 46 000 acre-ft.; Barrett, 27 675 " "; 73 675 acre-ft.	6.4	5.43	5.4	19.36 " 1912 / 15.00 " 1913
Increase yield by Barrett Dam	1.8	1.57	1.9	5.0 " 1913

Mr. Cory. In 1907, Mr. O'Shaughnessy became Chief Engineer of the Southern California Mountain Water Company, supplying water to the City of San Diego. On June 5th, 1912, the City bought the property, and the bond election was held on August 15th, 1912. The vote was 6 948 to 1 405, due to assurances from the company that the plant output was a "sufficient supply of water to take care of the increased population and growth which the Panama Canal and other factors are bound to create."* The mean daily consumption in 1912 was 5 819 214 gal., and in 1913, 6 850 000 gal., the city's growth being rapid.

The system then included the Otay and Morena supplies, which were then held by Mr. O'Shaughnessy as being good for 13 500 000 gal. daily. In April, 1914, at a hearing before the California Railroad Commission in connection with related matters, Mr. O'Shaughnessy testified that he had in the past year and a half reduced his estimate of the safe yield from Morena Reservoir to 6 500 000 gal. daily, the safe yield from Otay remaining at 400 miners' inches, equivalent to 5 160 000 gal. daily. He also testified that in 1912 he had considered Cottonwood Creek, fully developed, to be good for 1 500 miners' inches (however, presumably with 46 000 acre-ft. of storage at the Barrett Dam), but now estimated that with the creation of 27 675 acre-ft. of storage at the Barrett Dam site, and the 46 000 acre-ft. of storage existing at Morena, the safe yield would be 15 000 000 gal. daily; and that the present safe yield could be increased by 5 000 000 gal. daily by creating 27 675 acre-ft. of storage at Barrett.† The Engineering Department of the Railroad Commission at the same hearing determined the safe yield of the Otay as 2 500 000 gal. daily; of the Morena, 3 500 000 gal. daily; from the Cottonwood, complete development, 5 400 000 gal. daily; and the increase in safe yield by the construction of the Barrett Reservoir, 1 900 000 gal. daily.

Within less than a year, San Diego realized that the water supply must be increased, and Mr. O'Shaughnessy and J. B. Lippincott, M. Am. Soc. C. E., were called in to report on additional proposed sources of supply, including the San Luis Rey River at what is known as the Warner Dam site. Mr. O'Shaughnessy, at the same hearing before the Railroad Commission, estimated the safe yield from this source at 13 000 000 gal. daily‡.

Table 10 should be considered in connection with Mr. O'Shaughnessy's criticisms of the writer's presentation of the safe yield from local sources based on investigations by several local engineers and Brig.-Gen. H. M. Chittenden (*Retired*), and A. O. Powell, of Seattle; William Mulholland and J. B. Lippincott, of Los Angeles;

* "Construction of the Morena Rock Fill Dam, San Diego County, California," by M. M. O'Shaughnessy, M. Am. Soc. C. E., *Transactions*, Vol. LXXV (1912), p. 51.

† Transcript of Evidence, Application No. 547, California Railroad Commission, pp. 637 ff and 675, and Exhibit 10.

‡ *Ibid*, p. 675.

George G. Anderson, of Denver; Allen Hazen, of New York City; and Leonard Metcalf, of Boston, all Members, Am. Soc. C. E.; the Army Board, and, respecting the sources available for the East Bay cities, accords with his own conclusions. Mr. Cory.

It is interesting to note in Table 10 that if the available storage in the Tuolumne water-shed is 1 000 000 acre-ft., as estimated by the United States Geological Survey, the safe net yield (95% dry year standard) is only 1 066 000 acre-ft. Using the maximum storage in the basin, as taken by the writer, 1 500 000 acre-ft., the safe net yield is 1 275 000 acre-ft. This storage Mr. Burton Smith considers entirely too high, without exceeding a reasonable cost per unit capacity. Should it be possible to create 1 800 000 acre-ft. of storage in twenty-six reservoirs, as Mr. O'Shaughnessy proposes, the net safe yield would be 1 380 000 acre-ft. The writer, however, knows of no one except Mr. O'Shaughnessy who has ever suggested the possibility of developing such a tremendous quantity of storage.

Mr. O'Shaughnessy quotes from a report by Mr. John R. Freeman, dated March 21st, 1914, to the City Attorney and the City Engineer of San Francisco on "Reservoirs Ultimately Required for the Hetch Hetchy Water Supply of 400 Million Gallons Daily for San Francisco under the Terms of the Raker Bill." The writer has several times had occasion to review hydrographic estimates of Mr. Freeman, and has always arrived at results essentially similar to his. Accordingly, thinking the excerpt given was probably conditioned on assumptions as to irrigation needs, etc., permission to examine the report was asked. He was advised by the City Engineer that the report was not a public document, and permission to see it was refused. Comment on the report or the quotation from it, therefore, is impossible.

The writer is very much surprised that Mr. O'Shaughnessy should express inability to understand the writer's statement that the City had revised the estimated cost of the first 160 000 000 gal. daily installation from Mr. Freeman's figures of $37 501 400 to $64 000 000. The conference between the representatives of the Turlock and Modesto Irrigation Districts and the City Engineer and City Attorney of San Francisco, held in Washington while the Raker Bill was being framed, resulted in several drafts of the bill. One printed on June 23d, 1913, provided that the irrigation districts, before demanding any stored water, should, whenever the Director of the United States Reclamation Service might require, provide additional storage at an initial cost, not to exceed $15 per acre-foot of storage capacity. In the bill as passed all provisions requiring the irrigation districts to do anything positive were eliminated, by the House Committee on Public Lands, for legal reasons. However, in discussing this June 23d, 1913, draft of the Raker Bill, it was asked that such limiting cost per acre-foot of storage be raised from $15 to $20. The irrigation

Mr. Cory. districts' representatives declined, pointing out that, according to the Freeman estimate, the construction of the Hetch Hetchy Dam to its initial proposed height would create storage costing only $12.50 per acre-foot, and when continued up to the final height of 300 ft. (capacity then 330 000 acre-ft.), would reduce the cost to $8.50 per acre-foot. The City Engineer denied this, and stated that his revised estimates of the Hetch Hetchy Dam showed the cost to be in excess of $20 per acre-foot, and, further, that his estimate for the entire Freeman first installation was also much greater, and in fact was $64 000 000. These statements were official utterances of the City Engineer at official conferences with official representatives of the irrigation districts. Recently, on being reminded of this by the writer, Mr. O'Shaughnessy answered by saying that the too low unit prices of Mr. Freeman were just about offset by reductions resulting from no irrigation waters being permitted to be brought to the Bay region. However, on page 123* he says:

"Thus far, no radical departure from the Freeman plans is proposed, except that it may be considered advisable to install initially a smaller pipe line, 45 miles long, across the San Joaquin Valley for a supply of 60 000 000 gal. per day, and to develop at once 50 000 hydro-electric horse-power."

The differences in cost between 45 miles of pipe with respective capacities of 60 000 000 and 160 000 000 gal. daily, can hardly equal the increase of the City Engineer's estimate of $64 000 000 over the Freeman estimate of $37 501 400.

The writer, the Army Board, and Mr. O'Shaughnessy are in entire agreement as to the very great desirability for San Francisco Bay Cities to determine soon what distant water supply source or sources will ultimately be wanted, and immediately arrange for the necessary water rights. Special legislation granting to the Bay region the water rights desired and protecting these rights indefinitely until it may be found desirable to develop the sources, can be obtained almost for the asking from any session of the State Legislature. Even if a Constitutional amendment should be necessary, very little more effort would be required, as the sentiment throughout the State is certainly almost unanimous in favor of assisting important communities to plan intelligently in broad, far-seeing ways for their water needs especially.

Quotations of the cost of developing electrical energy in the hydro-electric and the steam plants, respectively, of the Pacific Gas and Electric System, as set forth in Application No. 400 before the California Railroad Commission, are made as a "refutation of this theory" as to the value of hydro-electric power in the Hetch Hetchy project as expressed by Mr. Grunsky and the writer. The Pacific Gas and

* *Proceedings*, Am. Soc. C. E., for January, 1915.

Electric Company's load factor is about 62%; the hydro-electric plants are naturally run all the time possible, and have a much higher load factor, and the steam plants a much lower load factor. Hence the load factor of the combined hydro-electric plants is more than three times that of the combined steam plants. It is almost an axiom that, with any given set of conditions, the relative economy of hydro-electric and steam plants is determined by the load factor. As a matter of fact, the writer's comments in the paper concerning the value of hydro-electric power are believed to be entirely fair, candid, and correct. Mr. Cory.

In several places Mr. O'Shaughnessy, both definitely and by inference, states that the Raker Bill contains provisions requiring the irrigation districts to develop water storage of their own. As already explained, in the original negotiations between the representatives of San Francisco and the irrigation districts, a plan was worked out whereby the irrigation districts were to provide storage as should be required by the Director of the Reclamation Service. The House Committee on Lands, however, decided that Congress, in framing the bill, had power to impose conditions of performance only upon the grantee. Accordingly, all of such provisions were eliminated, and the legislation, as passed by Congress, and the provisions thereof officially accepted by the City of San Francisco, contain no reference or implication requiring the irrigation districts to provide any additional storage.

The following quotations should be read in connection with Section 9 of the Raker Bill itself.

"Moreover, as explained by the Army Board to the Committee on Public Lands, should a controversy ever arise between the City and the irrigationists as to their respective rights, domestic consumption being the highest use to which water can be applied, under the laws of the State of California, the rights of the City will be paramount."

"Pending the construction of additional reservoirs by the irrigation districts, the Raker Bill provides that whenever the districts desire water in excess of that to which they are entitled under the terms of the bill, the City, on the demand of the districts, shall sell such quantities of stored water as may be needed for the beneficial use of the districts—without impairing the supply for domestic requirements—at such a price", etc.

"It is provided, however, that the City may require the irrigation districts to purchase a minimum quantity of stored water, and shall not be required to furnish more than a maximum quantity, in any calendar year, the minimum and maximum quantities to be fixed by the Secretary of the Interior, keeping in mind the superior needs of domestic use."

"It is not within the range of probability that if during any year the City's supply of stored water should be brought so low as to make

Mr. Cory. a water famine imminent, she should still be compelled to furnish water to the districts," etc.

The Raker Bill, though specifically stating that it does not interfere in any way with the laws of the State of California, grants the use of certain lands and rights of way in the Yosemite National Park and the Stanislaus National Forest only upon certain conditions which Congress imposed as entirely extraneous and having no relation whatever to California laws. The text of the bill with respect to these is as follows:

"Sec. 9, that this grant is made to the said grantee subject to the observance on the part of the grantee of all the conditions hereinbefore and hereinafter enumerated:

* * * * * * *

"(*b*) That the said grantee shall recognize the prior rights of the Modesto irrigation district and the Turlock irrigation district, as now constituted under the laws of the State of California, or as said districts may be hereafter enlarged to contain in the aggregate not to exceed three hundred thousand acres of land, to receive two thousand three hundred and fifty second-feet of the natural daily flow of the Tuolumne River, measured at the La Grange Dam, whenever the same can be beneficially used by said irrigation districts, and that the grantee shall never interfere with said rights.

"(*c*) That whenever said irrigation districts receive at the La Grange Dam less than two thousand three hundred and fifty second-feet of water, and when it is necessary for the beneficial use to receive more water the said grantee shall release free of charge, out of the natural daily flow of the streams which it has intercepted, so much water as may be necessary for the beneficial use of said irrigation districts not exceeding an amount which, with the waters of the Tuolumne and its tributaries, will cause a flow at La Grange Dam of two thousand three hundred and fifty second-feet; and shall also recognize the rights of the said irrigation districts to the extent of four thousand second-feet of water out of the natural daily flow of the Tuolumne river for combined direct use and collection into storage reservoirs as may be provided by said irrigation districts, during the period of sixty days immediately following and including April fifteenth of each year, and shall during such period release free of charge such quantity of water as may be necessary to secure to the said irrigation districts such four thousand second-feet flow or portion thereof as the said irrigation districts are capable of beneficially directly using and storing below Jawbone creek: Provided, however, That at such times as the aggregate daily natural flow of the watershed of the Tuolumne and its tributaries measured at the La Grange Dam shall be less than said districts can beneficially use and less than two thousand three hundred and fifty second-feet, then and in that event the said grantee shall release, free of charge, the entire natural daily flow of the streams which it has under this grant intercepted.

"(*d*) That the said grantee whenever the said irrigation districts desire water in excess of that to which they are entitled under the foregoing, shall on the written demand of the said irrigation districts sell to the said irrigation districts from the reservoir or reservoirs of the said grantee such amounts of stored water as may be needed for the beneficial use of the said irrigation districts at such a price as will return to the grantee the actual total costs of providing such stored water, such costs to be computed in accordance with the currently accepted practice of public cost accounting as may be determined by the Secretary of the Interior, including, however, a fair proportion of the cost to said grantee of the conduit, lands, dams, and water-supply system included in the Hetch Hetchy and Lake Eleanor sites; upon the express condition, however, that the said grantee may require the said irrigation districts to purchase and pay for a minimum quantity of such stored water, and that the said grantee shall be entitled to receive compensation for a minimum quantity of stored water and shall not be required to sell and deliver to the said irrigation districts more than a maximum quantity of such stored water to be released during any calendar year: Provided, however, That if the said irrigation districts shall develop sufficient water to meet their own needs for beneficial use and shall so notify in writing the Secretary of the Interior, the said grantee shall not be required to sell or deliver to said irrigation districts the maximum or minimum amount of stored waters hereinbefore provided for, and shall release the said districts from the obligation to pay for such stored water: And provided further, That said grantee shall without cost to said irrigation districts return to the Tuolumne River above the La Grange Dam for the use of the said irrigation districts all surplus or waste water resulting from the development of hydro-electric energy generated by the said grantee. Mr. Cory.

"(*e*) That such minimum and maximum amounts of such stored water to be so released during any calendar year as hereinbefore provided and the price to be paid therefor by the said irrigation districts are to be determined and fixed by the Secretary of the Interior in accordance with the provisions of the preceding paragraph.

"(*f*) That the Secretary of the Interior shall revise the maximum and minimum amounts of stored water to be supplied to said irrigation districts by said grantee as hereinbefore provided, whenever the said irrigation districts have properly developed the facilities of the Davis Reservoir of the Turlock Irrigation District and the Warner-Dallas Reservoir of the Modesto Irrigation District to the fullest practicable extent up to a development not exceeding in cost $15 per acre-foot storage capacity, and whenever additional storage has been provided by the said irrigation districts which is necessary to the economical utilization of the waters of said watershed, and also after water losses and wastes have been reduced to such reasonable minimum as will assure the economical and beneficial use of such water.

"(*g*) That the said grantee shall not be required to furnish more than the said minimum quantity of stored water hereinbefore provided for until the said irrigation districts shall have first drawn upon their own stored water to the fullest practicable extent.

"(*h*) That the said grantee shall not divert beyond the limits of the San Joaquin Valley any more of the waters from the Tuolumne watershed than, together with the waters which it now has or may hereafter acquire, shall be necessary for its beneficial use for domestic and other municipal purposes.

*　*　*　*　*　*　*

Mr. Cory.

"(*j*) That by 'the flow,' 'natural daily flow,' 'aggregate daily natural flow,' and 'what is naturally flowing,' as are used herein, is meant such flow as on any given day would flow in the Tuolumne River or its tributaries if said grantee had no storage or diversion works on the said Tuolumne watershed."

It will be noted that Paragraph (*f*) does not require the construction of any storage by the Turlock and Modesto Irrigation Districts, but, instead, requires the Secretary of the Interior to revise the maximum and minimum quantity of stored water referred to in Paragraph (*e*) whenever, and if, certain things occur.

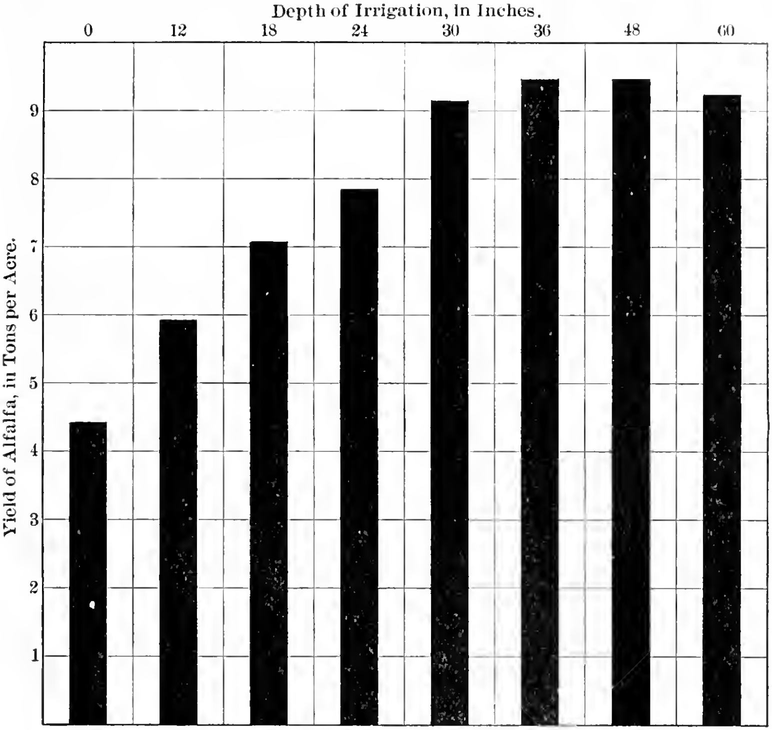
One further excerpt is given from Mr. O'Shaughnessy's discussion:

"The Hetch Hetchy scheme has been the subject of very serious consideration by many engineers who, after comparing it with all other available sources of water supply, have endorsed it. The engineers who have questioned it, with the sole exception of those employed by the irrigation districts, have been the representatives of special competing interests, hoping to dispose of their own private holdings for their own private gains."

Mr. Van Norden expresses a radically different opinion. It certainly would be interesting, and doubtless very helpful to the local comunities, to know what the consensus of opinion among local engineers really is. The writer suggests that Messrs. O'Shaughnessy and Van Norden co-operate in arranging for the San Francisco Association of Members of the American Society of Civil Engineers to carry out a confidential poll of the local Members and Associate Members of the Society—of which there are more than 130—or better yet, of all the societies which joined in holding the recent International Engineering Congress.

Turning now to the criticism, by Messrs. Rhodin, Sloan, and Brown, of the presentation in the paper of the Eel River source, it may be said that Eel River was given about as much attention as the Army Board gave it. Incidentally, the safe yield of this source, as given in Table 10, is exactly that found by the Army Board, which, however, also finds that with a conduit of 225 000 000 gal. daily capacity, and utilizing considerable local storage, the safe yield could be increased to 200 000 000 gal. daily. The writer has not checked these figures. Should the East Bay cities continue to keep aloof from San Francisco and its water plans, as Mr. Sloan suggests, they would probably find Eel River the most attractive and available mountain supply—possibly at the lowest cost per thousand gallons of any distant water under any arrangement.

Mr. Grunsky and others refer to the local sentiment regarding Sierra water. It undoubtedly is strong, which is interesting, and so is the reason for its existence. Sacramento, situated at the very edge of the Sierras' western foot-hills, is overwhelmingly in favor of filtered Sacramento River water. Human nature in the two cities is doubtless practically the same, so that the difference in the public sentiment in this regard is doubtless due to the respective communities having had engineering advice along different lines. The real enthusiasm with which San Francisco people greeted Mr. Grunsky's Tuolumne project in 1902 was probably because it was the first concrete Mr. Cory.



DUTY OF WATER ON ALFALFA-EXPERIMENTAL PLAT
DAVIS, CAL.–1910, 11, 12, 13, AND 1914.

Mean Annual Rainfall of Period:
At Davis, Cal. — — — — — — — 16.36 in.
On Turlock-Modesto lands — — 11.00 "
Difference — — 5.36 in.

FIG. 29.

plan put forward under the new charter, whereby the "yoke" of the Spring Valley Water Company might be thrown off and that corporation crumpled.

The writer has been much interested in the expressions of opinion concerning the water needs of the 300 000 acres in the Turlock and Modesto Irrigation Districts. However, summarizing the essential facts, concerning which there seems to be general consent, it appears

Mr. Cory. that the adaptation of most of the area is alfalfa, dairying, and stock; that six irrigations per annum are required for maximum economical yield; that the soil is, broadly speaking, rather sandy; and that the mean annual rainfall over the territory is 11 in., of which little, and frequently none, occurs in the cropping season.

Consequently, the writer sees no occasion to modify his ideas on the subject expressed in the paper, and especially the opinion that ultimately the total irrigation needs per gross acre in this area and in the Imperial Valley will prove to be practically the same—about 3.33 acre-ft. In reference to this matter, Fig. 29* is instructive.

Since writing the paper, more than a year and a half ago, the following important developments in the water situation have occurred:

1.—The jurisdiction of the Railroad Commission has been extended to the control of all public utilities, inside as well as outside of municipalities.

2.—The city officials and the Spring Valley Water Company agreed upon a sales price for all the latter's property which it was deemed advisable to purchase. At a special election, the proposition received a majority but not the necessary two-thirds affirmative vote.

3.—An election was held in the East Bay cities for the formation of a municipal water district, but the proposition was defeated.

4.—The Richmond Municipal Water District voted against authorizing a bond issue for bringing water from the Sacramento River.

5.—The Marin Municipal Water District has condemned before the Railroad Commission the property of the Marin Water and Power Company and the North Shore Water Company. The companies, feeling that the price fixed by the Railroad Commission was too low, have appealed to the State Supreme Court.

* This is Plate 4 of *Bulletin No. 1*, "Progress Report of Co-operative Investigations in California, 1912–1914" by Frank Adams, Irrigation Investigations, Office of Experiment Stations, United States Department of Agriculture, published by the California State Department of Engineering, 1915.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

PEARL HARBOR DRY DOCK

Discussion.*

By H. R. Stanford, M. Am. Soc. C. E.†

H. R. Stanford,‡ M. Am. Soc. C. E. (by letter).—The writer is extremely grateful to those who have been interested enough to discuss his paper and extends to them his thanks and appreciation. Mr. Stanford.

No attempt will be made in this closing discussion to consider any remarks or opinions expressed in preceding discussions, which are controversial in character, inasmuch as the paper only purports to be a record of facts and conditions. Careful effort will be made, however, to answer all questions which have been raised, and to supply the additional data or information requested.

In reply to questions raised by Mr. Taft, it may be stated that dilution with fresh water of the sea water contained within the cofferdams, in order to reduce the saline content and to avoid the deleterious effects of salt water on freshly placed concrete, was considered, but the idea was necessarily abandoned because of the limited supply of fresh water.

Experimental cubes of tremie-placed concrete, measuring 6 ft. on the side, were made with one brand of German cement and two brands of American cement, in order to determine, if possible, whether the use of a special brand of cement for tremie concrete would be warranted. These experiments indicated that "Santa Cruz" cement, which had been approved for the work, gave results as good as those obtained with the other test cements, and that the kind of cement which had been used was not chargeable with the trouble experienced with the tremie concrete.

The cement approved for use in the dock is the "Santa Cruz" brand, made at Davenport, Cal., subject to the standard Navy Depart-

* Discussion on the paper by H. R. Stanford, M. Am. Soc. C. E., continued from December, 1915, *Proceedings*.

† Author's closure.

‡ Washington, D. C.

Mr. Stanford. ment specifications, from which the following, relative to chemical requirements, is quoted:

"The cement shall be the product obtained by finely pulverizing clinker produced by calcining to incipient fusion an intimate mixture of properly proportioned argillaceous and calcareous substances, with only such additions subsequent to calcination as may be necessary to control certain properties. Such additions shall not exceed 3% by weight of the calcined product.

"In the finished cement, the following limits shall not be exceeded:

"Loss on ignition for 15 min.	4.00%
Insoluble residue	1.00%
Sulphuric anhydride (SO_3)	1.75%
Magnesia (MgO)	4.00%"

The importance of the proper mechanical mixing of the concrete in a batch is fully recognized, and steps have been taken to insure that there shall be no failure in this respect due to mixing for too brief a period or at too rapid a rate.

The experimental investigations in the use of tremies, which were conducted in connection with this work, did not give much consideration to methods of freeing the tremie from water when it was being charged at first. This apparent neglect was due to the fact that the straw pillow or plunger inserted in the tremie when the process was started practically prevented the salt water from entering all but the very first portion of the concrete charge and this part of the concrete, under any circumstances, would necessarily become impregnated with salt water when issuing from the tremie to begin the filling of the form. The straw pillow remained in the bottom of the form and was so compressed as to be unobjectionable under these conditions; an elaborate or expensive plunger was not considered justified.

In reply to a question by Mr. Pretty: a contour survey of the dock site, made before construction work was started, showed that the surface of the ground sloped quite uniformly from an elevation of approximately 14 ft. above mean low water at the head of the dock to an elevation approximately 10 ft. below mean low water at the entrance.

For a distance of approximately one mile from the open sea, the entrance channel to the Naval Station is straight, and has been dredged to provide a least width of 600 ft. The remainder of the channel has a least width of 500 ft. in the straight portions, and somewhat greater widths in curves. The minimum radius of the dredged channel is 1 600 ft. The safe speed for deep-draft vessels through this channel is from 4 to 6 knots per hour. There are large areas within the harbor, in the vicinity of the Naval Station, over which the natural depth of water is much in excess of that required by naval vessels, and this rendered the dredging of turning basins unnecessary.

The history of dry-dock construction in America is apparently much the same as that in other countries. With the authorization of each new large dock, effort was made to anticipate the growth of ships and to make the dock large enough to admit the largest vessel which would probably be built; due to the very rapid increase in the dimensions of ships, however, it has frequently been the case that when the docks were completed, usually after protracted delays from one cause or another, they had actually been outgrown during the period of construction. When dimensions were fixed for the locks of the Panama Canal it was expected that those dimensions would establish limits in the design of new ships for both the naval and merchant services, and, when the dimensions of the Pearl Harbor dock were made to accord with the Panama locks, the designing engineers had satisfaction in the thought that this would be one dock at least which would not be outgrown. Mr. Stanford.

The revised plans do not provide for the use of any imported silicious sand in making concrete for the body of the dock, except for the small quantity of tremie-placed concrete required for making the seals between adjacent sections. It is expected that the rich mixtures specified will result in making a practically impervious concrete which will insure the mass against depreciation from chemical changes and disintegration and will efficiently protect the embedded steel.

The vertical reinforcement rods near the outer vertical faces of the side-walls of the dock are $1\frac{5}{16}$ in. in diameter and 17 ft. long, and are 18 in. apart. The specified limits of ultimate tensile strength of these rods is from 55 000 to 70 000 lb. per sq. in., which is a safe limit, without making any allowance for increase resulting from the mechanical process of twisting or deforming. The sectional area of all embedded steel is made heavy as a protection against corrosion losses.

The method of building the side-walls first and then constructing the bottom between the walls was given very careful consideration, but the cost and difficulty in arranging details of construction, which would avoid the necessity for any considerable quantity of under-water placed concrete in building the central portion of the dock, led to the abandonment of the idea.

There are three large naval docks, which have been in operation for some time, each of which is unwatered by four vertical-shaft pumps operated by 2 200-volt motors. No trouble whatsoever has been experienced with these motors, either as result of the varying head on the pumps, or in starting or stopping the motors. The suggestion that the motors might advantageously be equipped with slip-rings and controllers, in order to obtain a certain degree of speed regulation, is a point well taken: with a 10% control, it is practicable to regulate the power input into the motor so that it will remain almost constant

Mr. Stanford. during the entire range of pumping, and this is a very material item, considering that the dry-dock load imposes the peak load condition on the power plant, and that maximum motor efficiency is of little consequence, because of the brief and infrequent intervals of pumping. It has been found in service that four pumps for one dock is a very desirable number, to provide for the regulation of unwatering in docking a ship, and also for break-down service; to increase the number with corresponding reduction in unit capacity would tend to add to the cost of the installation, on account of the expense of their valves and connections.

Each of the five pontoons of the floating dock is divided by a water-tight center bulkhead into two water-tight compartments; each of these compartments is further subdivided by swash bulkheads into four sub-compartments. All pumping is performed from the side-wall compartments, and each pontoon compartment can be pumped from either side-wall.

The small floating dock is being provided by the contractor as an item of plant necessary for the construction of the graving dock. The Navy Department fully recognized the great value which this floating dock would have as a permanent feature of the station's equipment on the completion of the graving dock, but, in view of the difficult and more or less hazardous character of the service which will be performed by the dock for the contractor, it was thought best to make the floating dock specifically an item of plant, in order to avoid the possibility of question as to responsibility in case of trouble.

Great care is being exercised in conducting the dredging operations, and in cutting off the tops of piles to avoid injury to the remaining piling which will form part of the prepared foundation for the dock. If any injury is suffered by this piling, it will be necessary to replace the injured piles with good ones.

The following are the estimated values, per linear foot of dock, of various elements in the completed structure, which will act in the nature of weights or ballast, in addition to the estimated force of 12 840 lb. due to the weight of concrete, to insure a positive downward resistance to flotation or uplift:

(*a*) Due to the weight and structural moment of the reinforced concrete ties in the surrounding crane track..	1 360 lb.
(*b*) Weight of soil on the narrow outstanding shelf in the outer face of the side-walls....................	11 160 "
(*c*) Probable average weight of concrete at 154 lb. per cu. ft., instead of 150 lb..........................	14 080 "
(*d*) Weight of blocking on floor of dock................	1 800 "
(*e*) Frictional resistance of earth against side-walls......	36 000 "
	64 400 lb.

Mr. Stanford.

Referring to the statement of Mr. Baterden that "it is a question whether a dry dock, 1 000 ft. long, is required in such a location", it should be noted that a dock having a lesser length would not comply with an implied requirement of the Act of Congress under which the dock is authorized. This reason is mandatory, aside from any consideration of military need.

The writer is in agreement with Mr. Baterden as regards the necessity, in general, for foundation piling for a concrete dock, even when constructed in soft ground. An essential reason for the great thickness of concrete in the floor of a graving dock, built in a reasonably favorable soil, is that it gives the dock sufficient weight to resist flotation; in other words, the dock weighs little more than the water which it displaces, and therefore imposes on the underlying soil a weight which is only a little more than that of the water which would naturally flood the completed excavation for the dock, and probably much less than that of the soil which was removed in making the excavation, and which in original formation had been safely supported for ages. Under these conditions, and in ordinary cases, there can be little need for piling if the dry dock structure is sufficiently strong to distribute its weight over relatively small soft spots in the bottom of the completed excavation, and the use of piling under such circumstances is in the nature of a precautionary measure or factor of safety.

Dredging for the channel was begun at the outer entrance, in water from 15 to 25 ft. deep, by using a steam lumber schooner fitted with hoppers and equipped with a 14-in. centrifugal pump, connected to a 20-in. suction pipe, and driven by a 275-h.p. steam engine. The suction pipe was rigged from an A-frame forward. This machine handled sand, loose coral, and mud very effectively in shallow water. As the depth became greater and the softer material was removed, a clam-shell dredge, equipped with a 4½-yd., 13-ton bucket, was put into use. This machine handled mixed materials as encountered, but did not remove successfully coral in ledge formation nor partly decomposed lava rock. For excavating these hardest materials a drag-scraper dredge, equipped with a 3-yd. bucket, was used; the bucket was sunk at the greatest possible distance from the dredge, which was moored with anchors, the water being too rough to permit the use of spuds, and was drawn in by a cable rove through a sheave at the stern of the dredge; the bucket was hoisted when a few feet forward of the hull. This dredge operated successfully on the hardest materials, and at the greatest depths, and was especially successful on the clean-up in cuts from 37 to 38 ft. deep, with a minimum of 35 ft.

A 16-in. suction-dredge, without cutter head, and operating from moorings, was used at the inner sections of the work. This dredge did not operate successfully in a seaway, and was used more extensively

Mr. Stanford.

on the less exposed parts. Attempts were made to operate both suction-dredges and a dipper-dredge from spuds in the entrance fairway, but there was always enough swell, even in the stillest weather, to render the use of spuds impracticable.

The dredging of the channel was begun August 23d, 1909, and completed on January 30th, 1912. During this period the weather conditions were generally favorable with no heavy tropical storms, although the dredges were frequently withdrawn to shelter on account of threatening weather. For months at a time the weather was fair, with trade winds springing up at about 10 in the morning and dying away between 4 and 6 in the afternoon. The evenings, nights, and early mornings were usually still. At the outer entrance, due to the trade winds, a fairly heavy swell was running at all times, and, as the deepening progressed, this extended farther and farther into the channel. The hard material in the entrance was broken up by drilling and blasting before cleaning up with the drag-line dredge. After the finished depth was nearly reached, considerable blasting was done without drilling, charges of explosives being placed on submerged boulders or ledges and fired by electricity. These blasts were quite effective, but only over a limited extent, and to a very limited depth.

The questions raised by Mr. Box are very interesting. In stipulating that the dock should be of the graving type, Congress was undoubtedly influenced by the fact that a dock of that type, after being completed, involved practically no expense for repairs and upkeep, whereas those costs for a dock of the floating type, with its mooring and approaches, are continuous and large. Although Congress is apparently willing to appropriate liberally to provide for the first cost of public works improvements, there is great difficulty in obtaining annual appropriations for maintenance and repair. Estimates for new works, therefore, are very apt to be larger than would otherwise be the case, to provide for very permanent and durable construction. As a business proposition, it would frequently be economical, in the long run, to spend less to begin with and a little each year for maintenance, so planning that the interest on the saving in first cost would more than equal the maintenance expense; but, knowing that there will be difficulty in obtaining the maintenance fund, there is a tendency to adopt the more extravagant method.

Floating docks have been found very efficient and satisfactory in the docking of our naval vessels, and there can be no question as to the practicability, value, and usefulness of docks of that type. The writer will frankly concur in the opinions expressed by Mr. Pretty, Mr. Bellamy, and Mr. Box, that the natural depth of water in Pearl Harbor, combined with the unfavorable soil conditions found at the

Naval Station, are strong arguments favoring the selection of the floating rather than the graving dock for that place. Mr. Stanford.

More thorough borings and examination of the ground conditions at the dock site before beginning operations would probably have obviated at least a part of the difficulty and expense which have been incident to the work. Such examinations, together with careful preliminary investigations of the material and labor resources in the vicinity, would also have shown that the first estimate of cost of the dock was quite inadequate. The explanation of the failure to obtain these data lies in the fact that there was a sudden realization of the importance of quickly developing this base, coupled with the altogether too frequent error of laymen in failing to recognize properly the importance and need of the engineer for such service.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

THE ASTORIA TUNNEL UNDER THE EAST RIVER FOR GAS DISTRIBUTION IN NEW YORK CITY

Discussion.*

By Messrs. William Cullen Morris and John Vipond Davies.†

William Cullen Morris,‡ M. Am. Soc. C. E. (by letter).—In relation to this paper, some information relative to the accident and casualty features of the work may be of interest. At the start of operations the Company decided, in view of the high rates prevailing for work of this class, to undertake the insurance instead of placing it with a casualty company. A very liberal policy was adopted by the Company in the treatment of the men, allowing them full time during incapacity owing to any cause (either illness or accident) and furnishing medical attendance and supplies during the period of disability. Field hospitals were maintained at each end of the tunnel, with orderlies in constant attendance. Arrangements were made with neighboring hospitals for prompt ambulance service in case of emergency, and every precaution was taken so that injuries could be treated to the best advantage. A physician was employed to supervise each of the hospitals, and the orderlies reported directly to these physicians all cases of first aid or disability treatment. Mr. Morris.

A force was organized for continuous inspection of the work, with a view of eradicating all preventable causes of accidents, the inspectors patrolling the work and immediately bringing to the attention of the tunnel force any features they might notice which might result in accidental injury. This feature of the work created some confusion for a time, but after several weeks of trying out, the arrangements

* Discussion of the paper by John Vipond Davies, M. Am. Soc. C. E., continued from December, 1915, *Proceedings*.

† Author's closure.

‡ New York City.

Mr. Morris. were perfected to such an extent that there was no interference with rapid progress.

The accident treatment record and accident prevention were all under the direct supervision of the Company's Engineer, Mr. Harold Carpenter, who reported to the Company's construction office.

The record of accidents throughout the work is as follows:

Total accidents	1 525
Serious accidents	115
Total time lost	1.78%
Cases sent to outside hospitals	24
Cases treated in tunnel hospital	67
Cost of accidents in relation to payroll	5.36%

Mr. Davies. JOHN VIPOND DAVIES,* M. AM. SOC. C. E. (by letter).—The very interesting contributions by Messrs. Freeman, Wiggin, and Wegmann, as to the experience in the Catskill Aqueduct, illustrate the principal points of difference between that undertaking and the Astoria Tunnel. In the latter the primary feature was the consolidation of the soft and partly decomposed rock in order to permit of the construction of the tunnel, and, secondarily, the filling of the fissures, for the purpose of stopping leaks. The primary feature in the case of the Catskill Aqueduct was the absolute filling of all voids and the stoppage of leaks, and, secondarily, the consolidation of the rock.

For the stoppage of leaks and the consolidation of the rock, considerable grouting had been done in 1892 and 1893 in the construction of the East River Gas Company's tunnel at 70th Street, Manhattan, referred to in the paper. At that time the writer ordered cement, specially burned, with the elimination of any plaster admixture, so as to obtain the most rapid setting material. That tunnel was constructed at a comparatively shallow depth, and there was so little cover between it and the bed of the river that high pressure could not be used. The same condition occurred in the construction of the Hudson and Manhattan Tunnels, where large quantities of cement grout were also used for the purposes just referred to, and, in that case, also, the comparatively shallow depth of these tunnels precluded any high-pressure grouting. In this latter case it was found that grout would follow the line of least resistance and pass out with little interruption into sewers, drains, or watercourses, without generally spreading into the soil, to give the results which were attained with the high pressures and greater resistances encountered in the Catskill Aqueduct and the Astoria Tunnel.

Mr. Sanborn inquires as to the erection of the vertical risers. These pipes were of cast iron, $2\frac{3}{4}$ in. thick, with hub and spigot joints. It was specified that they were to be machine-faced on the bearing

* New York City.

surfaces in hubs and ends of spigots, so that there should be a true fit at every joint. Unfortunately, the facing of the two ends was not executed from common centers, the result being that these pipes—which as designed should have given perfect vertical alignment—were, when erected, found to be in error, with a regular creep from the vertical, due to imperfections in foundry work, and this necessitated the use of wrought-iron shims to bring them into correct vertical alignment. Mr. Davies.

Mr. Lavis refers to the relations of mining engineers to the various tunnel operations now being carried on in New York City. It occurs to the writer that there is a general misunderstanding as to the use of the term "mining engineer" in this respect. In common with other engineers engaged on subway construction in New York City, the writer has been, to a considerable extent, brought up with coal mining and other underground operations. The timbering and methods of construction used by coal and metalliferous miners are as far removed from the methods of the engineer engaged in subway work as it is possible to conceive. The class of mining involved in subway and tunnel construction is distinctly a development of business, entirely apart from the ordinary practice of those engineers engaged in such purely mining operations. The men employed in England are known as "miners", but this class consists of those essentially engaged on engineering work in heavy soft ground tunneling, not in mining operations. A large majority of those engaged in this business in New York have learned their trade in Europe, or from those who have brought the art from Europe, and there should be no conflict in the distinction between so-called mining engineering and engineering connected with tunnel work. The so-called mining engineer knows little of the type of timbering used in these tunnels.

Mr. Forgie's contribution is so misleading that it is necessary to refer to it. The writer did not enter into a detailed description of the distortion of the short section of steel lining, as it involved no valuable engineering features. Fig 23 is in error as to the actual occurrence, because, with the rise of the invert, the sides went out wider than the so-called "correct shape", instead of coming in narrower, and there was a lift of the roof to a maximum extent of 2 in. With the removal of the two bottom plates, the sides were then drawn into correct position by turnbuckles before replacing the bottom plates and grouting.

Fig. 24 is also in error, as the blocking, as indicated, was not executed, except in the case of the wooden wedge blocks, which, as stated, were crushed under the load.

In reference to the statement as to the use of gravel and the blowing in of dry cement: These two items were used in an experimental way to a small extent, and in both cases proved failures, as all the

Mr. Davies. gravel and a large part of the dry cement were washed out through the grout holes, and proved of no permanent use or value. A few days after the actual execution of the work, examination through the grout holes, and other holes drilled through the lining, showed that a large proportion of the dry cement blown in had not set. That these various methods were only experimental is illustrated by the fact that on the first day of the experiment (August 25th) 587 bags of dry cement were injected at a pressure of from 45 to 75 lb., and on the following day, after injecting 70 bags additional, it was found that only 50% was effective, the remainder having washed out with the water. Therefore, the experiment of dry cement grouting was abandoned.

The other experiment, in which about 1½ cu. yd. of small pea gravel were used, was also unsuccessful, as the gravel was washed out with the flow of water as fast as it was put in.

There was a still further and partly successful experiment made by flooding the distorted portion, and grouting this section of lining while flooded with water under hydrostatic head. Long pipes were placed through the bulkheads and attached to grout holes at various points, and cement grout was injected through these pipes. By this method about 500 bags of cement were injected in the same section in which the dry cement and gravel experiments had been made.

This grouting under internal hydrostatic pressure effected a reasonably complete seal of the bottom segments, subsequent to which, timber bracing, as indicated by Fig. 15, was inserted, except that the timber braces were reversed, with radial arms in the lower section and vertical members in the upper section. Final grouting of this disturbed section was then efficiently completed.

The use of set-pins, or studs, was due to irregularity in the form of the cast segments, probably caused by deformation of the castings during the period of cooling, and the studs were used in order to obtain regularity in the setting without the use of loose wedges or other devices which might move out of place.

Mr. Morris calls attention to the provisions for attending to accidents and casualties. The writer desires to state that in the treatment of employees injured or incapacitated on this work, the Astoria Light, Heat and Power Company provided more liberally than any employer with whom he has had any previous experience. As there were no hospitals in the vicinity of the shafts, the officers of this company decided to build them especially for this work, and equipped them completely, not only for rendering first aid, but also for the actual treatment of cases under competent medical supervision. The adjustments with employees were most liberal, and it is of interest to note that, notwithstanding this great care and the liberality in all cases, the entire cost of the accident account amounted to only 5.36% of the pay-rolls.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

CONCRETE-LINED OIL-STORAGE RESERVOIRS IN CALIFORNIA: CONSTRUCTION METHODS AND COST DATA

Discussion.*

By Emile Low, M. Am. Soc. C. E.

Emile Low,† M. Am. Soc. C. E. (by letter).—The writer is very much interested in the method used in building up a compact and unyielding embankment in the construction of the oil-storage reservoirs described by Mr. Cole, and desires to record the method of building the earth embankments of the Hiland Avenue Reservoir of the new water-works, at Pittsburgh, Pa., of which the late William H. Kennedy, M. Am. Soc. C. E., was Chief Engineer, the writer during the entire construction of this reservoir occupying various positions of responsibility. Mr. Low.

The reservoir consists of two compartments (separated by an earth embankment), the larger one on the west and the smaller on the east side of Hiland Avenue. This street was closed and diverted, and its former site is now occupied by the division embankment. The site of the larger compartment had been occupied by market gardens, portions containing a deep, fertilized soil. The site of the smaller compartment had been covered by an apple orchard.

The reservoir is built on a comparatively level plateau overlooking the Allegheny River, just below the mouth of Negley's Run. The embankment extends around the entire periphery of the reservoir, except at the extreme western end, where, for a short distance, it is entirely in cutting.

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* Discussion on the paper by E. D. Cole, Assoc. M. Am. Soc. C. E., continued from November, 1915, *Proceedings*.

† Buffalo, N. Y.

Mr. Low.

The reservoir was to be partly in excavation and partly in embankment, and the first work was to clear the site of the embankment. In doing this, the rich top soil was first plowed, the loosened material being removed by two-horse scrapers and deposited immediately outside of the slope stakes. The underlying formation was generally clay. Cut-off ditches were then constructed, normal to the embankment slopes. These ditches were generally 8 ft. wide and from 2 to 4 ft. deep. They were excavated with plows and scrapers, and the removed material was placed on the cleared embankment site, which was first plowed, moistened, and rolled.

Owing to the large quantity of rich soil, much of which came from the market-garden plots, the outer slope of the embankment was built in an unusual manner. After the exact toe of the embankment had been fixed by slope stakes driven flush with the ground surface, the soil was deposited in a ridge about 2 ft. high, with a base about 6 ft. wide, carts being used for hauling.

Material from the cut-off ditches, and from the excavation inside the reservoir was placed next to this soil ridge in 6-in. layers, well watered, and rolled with a heavy cast-iron, grooved roller, drawn by two horses (or more after a rain). When the rolled embankment reached within 6 in. of the top of the ridge, more soil was deposited in a similar manner, great care being taken to have the outer surface conform to the prescribed slope, which was tested by level and measurement at frequent intervals. This method of placing the soil produced an interlocking effect. The specifications called for only 6 in. of soil, but the thickness actually averaged 12 in. or more, owing to the superabundance of this material.

The cut-off ditches previously referred to were refilled with suitable material, which was placed in thin layers, watered, and rolled. Care was taken to excavate these ditches below any roots.

In building the embankment, the lowest portions were filled first, care being taken to carry the layers up level, both longitudinally and transversely. On sloping ground the embankment was terraced or stepped, the cutting being usually 1 ft., the width depending on the slope. In transporting material from the excavation to the embankment, various methods were used. For short hauls near the embankments, two-horse scrapers were used. As the haul became longer, the scrapers were dumped into carts or wagons by drawing them over elevated timber platforms. Each platform had steep inclines and in the center there was a sliding trap door operated by hand. The filled scrapers were drawn up one incline, and after the team had passed the trap door, this was opened, the lip of the scraper was caught on a projection, and aided by the driver, this caused the scraper to turn over and deposit the material in the cart or wagon below, after which the team descended the other incline. Generally, the teams worked in a circle around each platform, and the latter was transported to another position whenever the limit of haul became too great. Mr. Low.

Another method of excavation was effected with a machine, consisting of a large box, supported by two pairs of wheels, and drawn by three horses. This box held about 1 cu. yd. At the front end, there was a slat elevator, operated by cogs and pinions. At the bottom of the elevator there was a scoop-shaped plow. The material was loosened by this plow and then forced upon the elevator and carried into the box. When the latter was full, the scoop or plow was raised and the whole machine was hauled to the embankment.

The bottom of this box consisted of a number of hinged slats, which, when turned, allowed the material to drop out gradually, forming a layer of about 4 in. This machine was an ideal one for building the embankment, first on account of the thin and even layers deposited, and, second, on account of the consolidation of the layers by the passage of the heavy loads over it. Notwithstanding this, rolling with the prescribed heavy grooved roller was never omitted, although it seemed at times to be a senseless requirement.

In excavating for the inner slope of the embankment, from 1 to 2 ft. of material was left undisturbed. As soon as the embankment reached this inner edge, the material was placed about 2 ft. inside the prescribed slope and also carried up steeper. The object of this was twofold: first, to obtain a solid embankment at the slope line; and second, to provide material for the puddle, which lined the inner slope from top to bottom.

The material on the site was generally clay, but there were quite large pockets of sand in the large compartment, and in its northern end there was also soft, sandstone rock, which latter was not allowed in the embankment, but was placed in spoil in an adjoining ravine.

Practically all the outer embankment was built of clay, a small quantity of sand being placed on the outer edge, and some intermingled with and deposited in thin layers at the same time as the clay.

In the division embankment the use of sand was allowed to a greater extent than in the outer embankment.

There was trouble from water in only one case, and this was where a spring issued near the outer edge of the northeastern embankment of the large compartment. This spring was merely walled in, and the water was carried off by an ordinary French drain.

In excavating at the south end of the eastern compartment quite a number of tile drains were unearthed. These passed under the site of the south embankment and emptied into a near-by ravine. In every case these drains were followed up and removed. The resulting excavations were roughened and widened, and then short cross-ditches were

Mr. Low. dug, all being refilled with suitable material, well moistened, and rammed by hand.

Water for moistening the embankment during construction and for other uses, was pumped from the Allegheny River, through a 1½-in. iron pipe, the pump being in one of the buildings of the Brilliant Oil Works, immediately above which the pumping station was under construction at the same time as the reservoir.

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PAPERS AND DISCUSSIONS

THE HYDRAULIC JUMP, IN OPEN-CHANNEL FLOW AT HIGH VELOCITY

Discussion.*

BY MESSRS. H. F. DUNHAM AND ROBERT F. EWALD.

H. F. DUNHAM,† M. AM. SOC. C. E.—In the early part of this discussion there was a reference to a value that was mysterious—a third root undefined in the cubic equation. It would be of interest to know whether that value could be satisfactorily accounted for by introducing a transverse depression, a negative "jump" in the canal, so that a further mathematical relation might be illustrated by both the analysis and the figure. It frequently happens that an undetermined root in a quadratic or cubic equation indicates a problem varying but little from the original and yet pointing to a new and unexpected meaning. Whenever this occurs, and a previously unnoted fact comes to light or to the surface, there is an added assurance of correctness in the first statement and an invitation to generalize more widely. Mr. Dunham.

ROBERT F. EWALD,‡ ASSOC. M. AM. SOC. C. E. (by letter).—With respect to the flow of water in open channels, Mr. Kennison discusses certain phases which have heretofore received rather scant attention from engineers in general. His mathematical deductions permit of the ready determination of the two limits of flow possible in open channels; one, in which as much as possible of the total head is converted into velocity head; the other, in which as much as possible of the total available head is retained as static head and the flow is still maintained at the stated rate. Mr. Ewald.

A feature of the paper of particular interest deals with the conditions under which the depth of the water may change from one to

* Discussion of the paper by Karl R. Kennison, Assoc. M. Am. Soc. C. E., continued from December, 1915, *Proceedings*.

† New York City.

‡ Alcoa, Tenn.

Mr. Ewald.

the other of the alternative stages. Mr. Kennison's mathematical studies lead to the statement, on page 1708:*

"The jump proper, or the passing from the lower to the upper stage, does not involve energy losses, except incidentally, and it is doubtful if the ordinary formula for loss by 'sudden expansion' applies in this case."

This statement may need modification, and perhaps should be strictly limited to rises occurring under conditions governed by actual external controlling sections, as defined in the paper, because there is ample evidence to show that, in channels of uniform cross-section and gradient, rises may be produced which are accompanied by considerable inherent energy losses, which losses are independent of channel conditions, and apparently conform to some law not yet definitely established. These energy losses, when very high velocities are con-

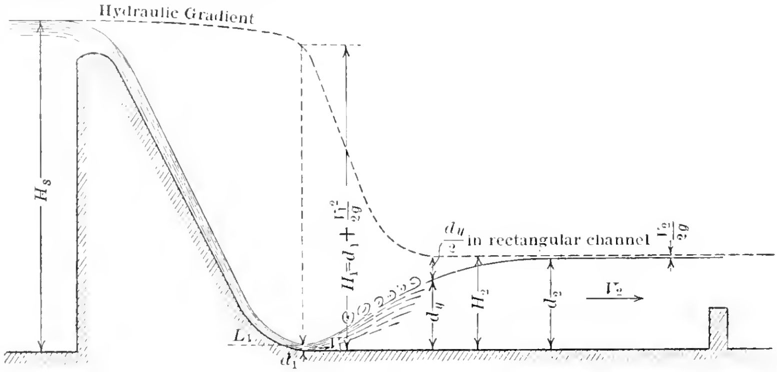

FIG. 28.

cerned, amount to a very large percentage of the original kinetic head, and become a factor of the greatest importance. If the existence of inherent energy losses is admitted, then the jump, in a sense, becomes a control, because within it, the hydraulic gradient is brought down to such a position as to permit of the change in levels. In order to render the actual conditions clearer, it will be necessary to refer to Fig. 28, which shows the ideal jump as developed at the toe of an overflow dam. An essential condition in this case is that the obstruction, or weir regulating the height of the jump, be far enough down stream to permit the water, after passing through the jump, to attain uniform flow parallel to the bottom before passing over the weir. Due to the inherent energy losses occurring in the water as it rises, the hydraulic gradient has been brought down from its high level at section d_1 to the much lower level at d_y. At the point, d_y, where the

* *Proceedings*, Am. Soc. C. E., for September, 1915.

Mr. Ewald.

gradient becomes nearly level and the depth of the water in a rectangular channel is two-thirds of the distance from the bottom of the channel to the hydraulic gradient, we have a condition in which the water is flowing, according to Mr. Kennison's theory, at the lower of two corresponding alternative stages for the total head, H_2. The higher stage for this value of H_2 is that existing at the section, d_2, and the water rises to this level from d_y without further loss of energy. Actually and theoretically, we have a condition then in which, discussing the jump as a whole, there is an inherent loss of energy, causing the drop of the hydraulic gradient and the establishment of a controlling section within the jump. The remainder of the rise is effected without considerable energy loss.

The writer includes the term "theoretically" in the previous paragraph, because he hopes that, ultimately, the science of hydromechanics will be advanced so that it will be possible to determine and explain, with a reasonable degree of accuracy, the losses of energy due to expansion, much in the same way as the electrical engineer is able to measure and foretell the effects of self-induction in alternating currents. Mr. F. zur Nedden, in his paper on "Induced Currents of Fluids,"* recognizes the existence of certain forms of energy losses in diffusors, which losses are independent of the roughness of the channel but do depend on the "rate of dilatation." As the jump is an expansion of section, and involves a retardation of velocity, it is reasonable to believe that the energy losses due to expansion are also an inherent feature of the jump, and must be recognized in all computations involving the expansion. It is possible that much of our knowledge concerning expansion losses will be gained by a thorough study of the jump, as experience indicates that, under conditions as nearly ideal as possible, it is extremely sensitive to very slight changes in conditions, and therefore permits of reasonably accurate measurements.

In studying the jump, recognition should be given to two forms: In one of these, the rise is effected by an external controlling section, and no energy losses occur, aside from those due to channel friction and a certain minor form of impact loss corresponding to that occurring in solid bodies and expressed by the term, $(1 - e)^2 \frac{(V_1 - V_2)^2}{2} M$, in which e is the coefficient of restitution. It is suggested that this form of the jump be designated as the "standing wave", as the term "wave" does not necessarily involve the idea of energy loss. (It will be noted that Mr. Groat has used the term "standing wave" in his discussion.) The second type of rise occurring in channels of uniform cross-section, involving certain inherent energy losses, and

* *Proceedings*, Am. Soc. C. E., for August, 1915.

Mr. Ewald. forming within itself the controlling section, may be designated as the "hydraulic jump", as the term has been used so frequently in connection with the discussion of energy losses at the toes of overfall dams, which cases usually involve rises of the type under discussion.

The Standing Wave.—The standing wave is formed when channel and external controlling sections are adjusted so as to produce flow in accordance with the conditions discussed by Mr. Kennison and Mr. Groat, and constitutes a type of rise which has been observed frequently. Examples of the standing wave are given by Mr. Kennison in Figs. 5, 7, and 8.* The flow over submerged weirs under certain conditions affords the most and best examples. The standing wave has been so ably handled by the author and those following him, that no further discussion will be attempted.

The Hydraulic Jump.—At the risk of being charged with presenting matters much too elementary, a brief discussion will be given of the action of the hydraulic jump under conditions as nearly uniform and ideal as it is possible to obtain. An ogee type, straight-crested, spillway dam is constructed in an open rectangular flume of dressed lumber. The cross-section of the flume is uniform, and the bottom is level. If water is allowed to pass over the dam, and the flow in the channel is unobstructed, the depth of the water, at the point at which the curved portion of the dam at the toe becomes tangent to the floor of the flume, will be that of the lower alternative level, corresponding to the head, H_1. H_1 is equal to the hydrostatic head on the dam, H_s, minus the head lost in friction in passing over the dam. The water will continue to flow at the low level, the depth gradually increasing, due to the retardation of the velocity by friction, until the hydraulic gradient has been brought down at a certain point to a distance above the channel bottom equal to $\frac{3}{2}$ of the depth of the water at that point. For the given hydraulic conditions, the channel cross-section now becomes a controlling section, and the water suddenly rises to the upper alternative level for the value of H at that point, or H_2. H_2 now equals H_1 minus the total friction head from the toe of the dam to this point. Where the velocity is high, a considerable length of the flume is required to lower the hydraulic gradient to the requisite height.

If, at a short distance toward the dam from the point where the rise is developed, a slight obstruction is placed across the channel, it is probable that sufficient energy will be absorbed in impact to bring the gradient down to the requisite height, and the wave will move up stream to or near the obstruction. Now, if slight increments are made to the depth of the water, the crest of the rise will move

* One is also shown in the central portion of Fig. 358 in the first edition of Mead's "Water Power Engineering."

toward the dam, and finally the initial point may be brought exactly to the toe of the dam. The conditions are now as shown in Fig. 28. The obstruction in itself does not develop the energy losses, and, as the velocity of the water over the channel bottom has been decreased, the effect of friction is decreased materially. The losses necessary to bring the gradient down to the position shown are developed within the rise. Experiments of this character have been performed frequently, and there seems to be a definite relationship between the velocities, V_1 and V_2, and the depths, d_1 and d_2; hence the conclusion that the energy loss is inherent, and is probably a determinable quantity. Mr. Ewald.

A few figures will be presented in order to indicate the extent of observed losses in the jump. On a dam, constructed in general according to Fig. 28, 4.08 ft. high above the floor of the flume, with a discharge of 0.580 cu. ft. per sec. per lin. ft. of crest, the depth of the water at d_2 was found to be 0.583 ft., and, with a Pitot tube, the velocity head at d_1 was found to be 3.17 ft., corresponding to a velocity of 14.29 ft. per sec. From the discharge, estimated from the head on the dam, which had been calibrated previously by a sharp-crested, suppressed weir, the depth of water at d_1 was estimated to be 0.041 ft. The value of H_1, then, must have been 3.17 + 0.041 = 3.211 ft. For this value of H_1, according to Mr. Kennison, the lower level depth should be 0.039, which checks out reasonably well with the observed figure, and the upper level depth would have been 3.2103. The obstruction, a movable weir crest, was placed 18 ft. down stream from the toe of the dam. Without any change in the character of the channel, at the point where the expansion occurred, an actual loss of head, amounting to (3.17 — 0.155) — (0.583 — 0.041) = 2.473 ft., took place within a distance in which, previously, not more than 0.01 had occurred, with a velocity of 14.29 ft. per sec. The loss amounted to 82.3% of the difference in velocity heads between d_1 and d_2, and 79.6% of the original velocity head.

Many of those who have read Mr. Kennison's paper, no doubt have looked up the description of the Truckee main canal chute, and read the account of the jump formed therein. Judging from the illustrations accompanying the description, at least 15 ft., or about 85% of the original velocity head, was absorbed in the jump. As this occurred in a relatively smooth channel, it is extremely difficult to conceive of any form of channel friction or other form of "incidental loss" that would account for the great loss of head that actually developed.

The various pictures of dams in action, given in the paper and in the discussions, give good visual evidence of the existence of large energy losses. In the case of the Bassano Dam, the fact has been

Mr. Ewald. pointed out by Mr. Muckleston that channel conditions, as influenced by the presence or absence of irregularities designed to increase impact losses, have relatively insignificant influence on the amount of head absorbed.

Where the jump is formed in a regular channel, on smooth surfaces, similar to the conditions for the dam in the flume, as just discussed, casual observation and simple tests reveal several interesting features. The quantity of water undergoing actual retrograde movement toward the dam is relatively small as compared with the total quantity flowing. A small quantity flows down the surface of the rise sloping toward the dam, and produces the appearance of considerable agitation. Pitot tube tests show that the velocities are almost always down stream, and decrease fairly uniformly. The absorption of energy, under these conditions, is accompanied by a minimum of sound, the sensation on the observer being that gained by listening to a good motor running at full load under the most efficient conditions, after the starting noise has subsided. The general impression is that fairly complete absorption of energy is taking place, without much influence on the channel. These remarks, of course, do not apply to channels in which irregularities of any considerable extent are to be found.

There is serious need of reasonably exact knowledge concerning the nature and extent of the energy losses involved in the jump. In connection with the design of dams, the jump, in itself, establishes the minimum hydraulic conditions under which the requisite expansion of section and reduction of velocities to safe limits may be accomplished. The position of the jump must be controlled at all stages, so that the expansion is effected on smooth aprons of material which will resist the initial velocity. This is true, not only of low dams and waste-ways, but also of high dams, in many of which the overfall velocities pass the limits of those which may be safely carried by the hardest rock. The necessity and dimensions of such aprons are matters which should be capable of ready determination while the dam is being designed. At present, there are no accepted rules or hydraulic formulas which will enable one to assert positively, in all cases, that the existing normal channel depth of water is or is not sufficient for the formation of the jump at the toe of the dam. Fortunately for most dams, the natural channel depths down stream from the dam are sufficient to maintain depths greater than necessary, and also, in most cases, the rise of the water below the dam is at a greater rate than on the crest, usually producing more stable conditions at the extremely high discharges than may be found at the intermediate stages. A particular case of this kind is pointed out by Mr. Muckleston.

Mr. Ewald.

It has been assumed, generally, that the mathematical expression for the lost head in the jump has the general form, $\frac{(V_1 - V_a)^2}{2\,g}$. This form probably is not far from the truth, when it is remembered that the work involved in retarding the velocity of a moving body from V_1 to V_2 ft. per sec., according to the principles of mechanics, has the general form, $\frac{M}{2}(V_1 - V_2)^2$. As the losses are partly effective in retarding the velocity of the water passing through the jump, it seems probable that the general expression for the loss will be a term of the form, $\frac{(V_1 - V_a)^2}{2\,g}$, in which V_a is to be considered as the average velocity that the water would have, assuming that the losses alone are effective in retarding the velocity. The final value of the velocity, V_2, has been used by several writers for V_a, but this, apparently, is inconsistent with the original assumption, as part of the reduction to the final velocity, V_2, is effected, during the vertical component of the path traversed by each particle of water, in direct action against the force of gravity, and the energy represented by this process reappears as static head. This is not lost head. The term, $\frac{(V_1 - V_a)^2}{2\,g}$, may also be expressed in the form, $\frac{\left[V_1 - (\sqrt{2\,g\,h'} + V_2)\right]^2}{2\,g}$, in which $\sqrt{2\,g\,h'}$ is to be considered as the average velocity retarded in rising against the "force of gravity" alone through the height, $d_2 - d_1$. The correct evaluation of the term, $\sqrt{2\,g\,h'}$, is necessary in order to obtain the true general equation for the jump. The true relation of the values of V_a or $\sqrt{2\,g\,h'}$ to the other factors entering into the jump, such as V_1, V_2, d_1, or d_2, has not yet been established. The limiting value of $\frac{(V_1 - V_a)^2}{2\,g}$ apparently is an expression of the form $\frac{(V_1 - k\,V_2)^2}{2\,g}$, in which $k\,V_2$ is to be considered as the velocity at that point in the jump at which the depth of water bears such a relationship to the height of the hydraulic gradient that the further rise of the water to the higher level down stream from this point is effected without further loss of energy, in accordance with Mr. Kennison's theory. This limiting value seems to be closely approached in jumps formed in water flowing at very high velocity, say, 10 ft. per sec. or greater. Assuming for the present that the actual value is the same as the limiting value, the following equations may be developed:

Mr. Ewald.

Neglecting friction losses, Bernouilli's theorem for the conditions shown in Fig. 28, may be written,

$$\frac{V_1^2}{2g} - \frac{V_2^2}{2g} - (d_2 - d_1) = \frac{(V_1 - k\,V_2)^2}{2g}$$

$$\frac{V_1^2}{2g} - \frac{V_2^2}{2g} - (d_2 - d_1) = \frac{V_1^2 - 2\,V_1\,k\,V_2 + k^2\,V_2^2}{2g} \quad \ldots\ldots(1)$$

Collecting terms:

$$\frac{2\,V_1\,k\,V_2}{2g} - (1 + k^2)\,\frac{V_2^2}{2g} = d_2 - d_1.$$

We also have the equation:

$$V_1\,d_1 = V_2\,d_2$$

and

$$\frac{d_2}{d_1} = \frac{V_1}{V_2} = \text{to } n \text{ (assumed).}$$

Then, in the foregoing equation:

$$\frac{2\,V_1^2\,k}{2\,g\,n} - (1 + k^2)\,\frac{V_1^2}{2\,g\,n^2} = (n - 1)\,d_1$$

$$\frac{V_1^2}{2g}\left(\frac{2\,k}{n} - \frac{(1 + k^2)}{n^2}\right) = (n - 1)\,d_1$$

$$\frac{V_1^2}{2g} = \left(\frac{n - 1}{\frac{2\,k}{n} - \frac{(1 + k^2)}{n^2}}\right)d_1$$

$$\frac{V_1^2}{2g} = \left[\frac{n^3 - n^2}{2\,k\,n - (1 + k^2)}\right]d_1 \quad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Also:
$$\frac{n^3 - n^2}{2\,k\,n - (1 + k^2)} = \frac{V_1^2}{2\,g\,d_1} \quad \ldots\ldots\ldots\ldots\ldots\ldots(2_1)$$

In a rectangular section in which the hydraulic gradient is but little higher than the surface of the water at d_2, the velocity at d_y is approximately $\frac{3}{2}\,V_2$ and the value of k is $\frac{3}{2}$. Substituting this value in Equation (2), we get:

$$\frac{V_1^2}{2g} = \left(\frac{n^3 - n^2}{3\,n - 3.25}\right)d_1,$$

which is the approximate expression for the jump in open rectangular channels, provided V_2 is so small that it makes k equal $\frac{3}{2}$ nearly. Values of the expression, $\frac{n^3 - n^2}{3\,n - 3.25}$, for values of n up to 20, have been plotted as a curve in Fig. 29.

Mr. Ewald.

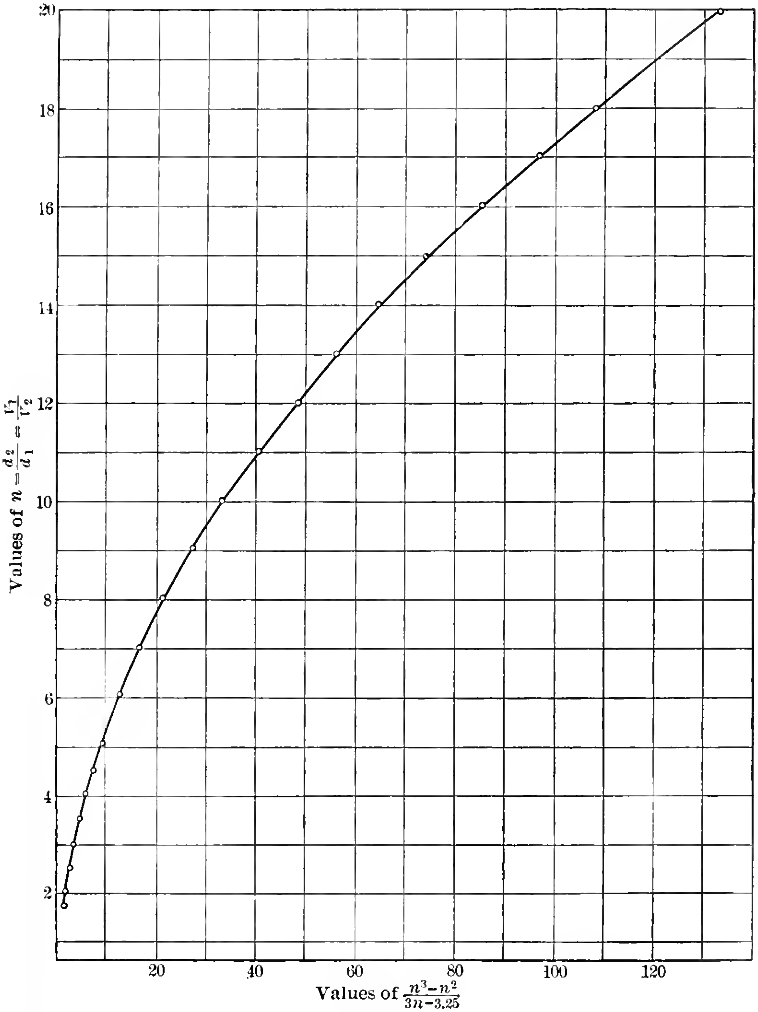

FIG. 29.

Mr. Ewald.

The application of this equation to a few examples of the jump will be given. One example, in which $V_1 = 14.29$; $d_1 = 0.041$; $V_2 = 1.00$; and $d_2 = 0.583$, has already been mentioned. For this case,

$$\frac{V_1^2}{2\,g\,d_1} = \frac{n^3 - n^2}{3\,n - 3.25} = \frac{3.17}{0.041} = 77.4.$$

Referring to the curve, the value of n is found to be about 15.2, and nd_1 becomes $15.2 \times 0.041 = 0.624$. The observed value of d_2 was 0.583.

The jump in the concrete chute of the Truckee Canal was not formed in a channel with a level bottom, and the equation is not exactly applicable. However, if it is assumed that the velocity of V_1 was 34 ft. for the limiting discharge of 90 sec-ft., d_1 would be 0.265, and

$$\frac{V_1^2}{2\,g\,d_1} = \frac{n^3 - n^2}{n - 3.25} = 68.$$

for which $n = 14.3$ and $nd_1 = 3.79$. The actual difference in elevation of the initial point of the jump on the slope and the surface of the water below the jump apparently is very close to 3.5 ft.

The limited data, based on Bidone's experiments, at present available to the writer, do not check the equation given, the value of n, as derived from the curve, being only 2.46, though the actual value was almost exactly 3.0 for the particular example quoted by Mr. Kennison. Bidone's experiments were made in channels having slopes of about 0.02, and the actual difference in elevation of the surface of the water at the initial point of the jump and the crest of the rise probably was considerably less than the value $(d_2 - d_1)$ used in deriving the equation. Also, as the value of V_2 was comparatively large, the value of k would differ from $\frac{3}{2}$ by a considerable amount. If the conditions of the experiments were actually as shown in Fig. 11, another reason for the discrepancy would be found in the fact that the obstruction forming the jump was nearly under the crest and deflected all the water upward toward the gradient to an extent sufficient to cause the obstruction, regardless of its small size, to act as an external controlling section, and form a rise more in the nature of the standing wave. Equation (2) will apply strictly only to those conditions in which the crest of the jump is far enough up stream to permit the water to attain a condition of uniform parallel flow before passing over the obstruction. The function of the latter is simply to maintain a depth of water sufficient to permit the minimum conditions under which internal absorption of energy can take place.

The flow of water over arched dams into channels of varying depth introduces complications necessitating individual study for each case. Observation indicates that in a dam having a uniform depth of water over the crest, the jump will be pushed farthest down stream in the shallower sections. This indicates that, instead of treating the cross-section as a whole, or averaging the depths, the entire cross-section should be divided into sections having bottoms of nearly uniform elevation, and treating each section as a rectangular channel, paying particular attention to the values of V_1 and d_1 for the water entering those sections. Mr. Ewald.

In summing up, it appears that there are certain types of rise in open channels in which there is little or no loss of energy, and that there are other types in which the inherent energy loss is very great. The latter type is of great importance to the designer of dams, waste-ways, etc., and merits much additional study.

AMERICAN SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

A STUDY OF THE DEPTH OF ANNUAL EVAPORATION FROM LAKE CONCHOS, MEXICO

Discussion.*

By Messrs. Robert Follansbee and L. R. Jorgensen.

Robert Follansbee,† Assoc. M. Am. Soc. C. E. (by letter).—Records at Santa Fé, N. Mex., from a 3-ft. floating-pan, show that the Piche method of determining evaporation gives results too great. The Piche records at Santa Fé give 79.8 in., and actual measurements from April, 1913, to September, 1914, show a mean of 59.2 in. On the other hand, the lines of equal evaporation on Fig. 3 show approximately 50 in. for Southwestern Oklahoma, though the floating-pan records, from February, 1913, to October, 1915, show a mean of 61 in., approximately. Mr. Follansbee.

On page 1731,‡ the authors state that the "adopted evaporation depth evidently is a gross depth; and, for use in the water-supply investigation, requires to be reduced by the average yearly depth of rainfall on the lake surface." If the discharge is measured at the point of inflow, this statement is correct, but if it is measured at or below the point of outflow, the rainfall should not be deducted, as it is already taken into account by the increased flow which it causes at the measuring point. Also, in water-supply investigations involving storage in a natural lake, evaporation does not enter into the calculation at all, if the discharge is measured at the outlet, unless the storage contemplated will increase appreciably the water surface of the lake, and then the evaporation should be applied only to the increased area, as that from the normal or natural water surface has already taken place, and the measured outflow shows the run-off less such evaporation.

* Discussion of the paper by Edwin Duryea, Jr., M. Am. Soc. C. E., and H. L. Haehl, Assoc. M. Am. Soc. C. E., continued from December, 1915, *Proceedings*.

† Denver, Colo.

‡ *Proceedings*, Am. Soc. C. E., for September, 1915.

Mr. Follansbee.

The authors' conclusion that the evaporation from a reservoir surface is somewhat less than 67.7% of the results obtained by a standard 3-ft. pan floating on the water, is of extreme importance in studies of storage, especially in the western sections of the United States. In the extensive studies of evaporation carried on by the Weather Bureau at Salton Sea, the coefficient, 62%, was obtained by comparison with records from a pan placed on a tower 2 ft. above the water surface. As these studies showed that the rate of evaporation depended on the distance the pan was placed above the water surface, and as Professor Bigelow, in his discussion of evaporation,* states that "evaporation is very sensitive to the atmospheric conditions within an inch or two of the surface of the water and to the temperature of the water," the writer, for one, was not convinced that the coefficient, 62%, would apply to records from floating-pans. For that reason, the conclusions reached by the authors are especially valuable. By comparison with the Salton Sea experiments, they seem to indicate that the rate of evaporation is nearly constant within a vertical distance of at least 2 ft. from the water surface itself, instead of being confined to a distance of a few inches, as was indicated by Professor Bigelow in his discussion quoted previously.

A contributing factor to the greater evaporation in floating-pans is the wetted strip around the inside of the pan, just above the normal water surface, caused by the wave action within the pan itself. This frequent wetting of the sides of the pan exposes an additional wetted area on a warm iron surface, and hence causes greater evaporation.

The writer was especially interested in the simple relations between evaporations and temperature for the records in the southern part of the Rio Grande drainage. To determine whether a similar relation exists for the upper part of the Rio Grande drainage at an elevation of 7 200 ft., the records near Santa Fé were investigated, and were compiled by the U. S. Geological Survey.† The equipment at the station consisted of a standard pan, 3 ft. square and 18 in. deep, which was floated on a small reservoir 1 mile west of Santa Fé (elevation 6 900 ft.) until May 1st, 1914, when the station was moved to the reservoir of the Santa Fé Water and Light Company, 2 miles east of Santa Fé (elevation 7 200 ft.). The record is given in Table 63.

The results were first plotted by using water temperatures, but, as the relation between evaporation and temperature is chiefly of value when used in determining evaporation when air temperatures only are available, the results were replotted, using the air temperatures recorded at Santa Fé. This latter plotting, Fig. 21, shows that the points do not lie on or near a single straight line, as would be the case if the simple relation between monthly evaporation and temperature

* "A Manual for Observers in Climatology and Evaporation."

† *Water Supply Papers Nos. 358* and *388*.

TABLE 63.—TOTAL EVAPORATION NEAR SANTA FÉ, N. MEX.

Mr. Follansbee

Month.	1913.		1914.	
	Evaporation, in inches.	Temperature* of air.	Evaporation, in inches.	Temperature* of air.
Jan.	....	....	1.96	33.5
Feb.	....	....	2.20	32.6
Mar.	....	....	3.85	39.4
Apr.	....	....	5.66	48.0
May	8.36	58.6	5.95	56.2
June	6.65	62.5	10.19	67.0
July	7.23	69.6	6.24	67.0
Aug.	6.37	68.6	5.97	66.8
Sept.	5.54	57.2	6.28	63.0
Oct.	5.15	47.8	....	....
Nov.	3.29	42.4	....	....
Dec.	2.66	26.4	....	....

* Taken from Weather Bureau records at Santa Fé.

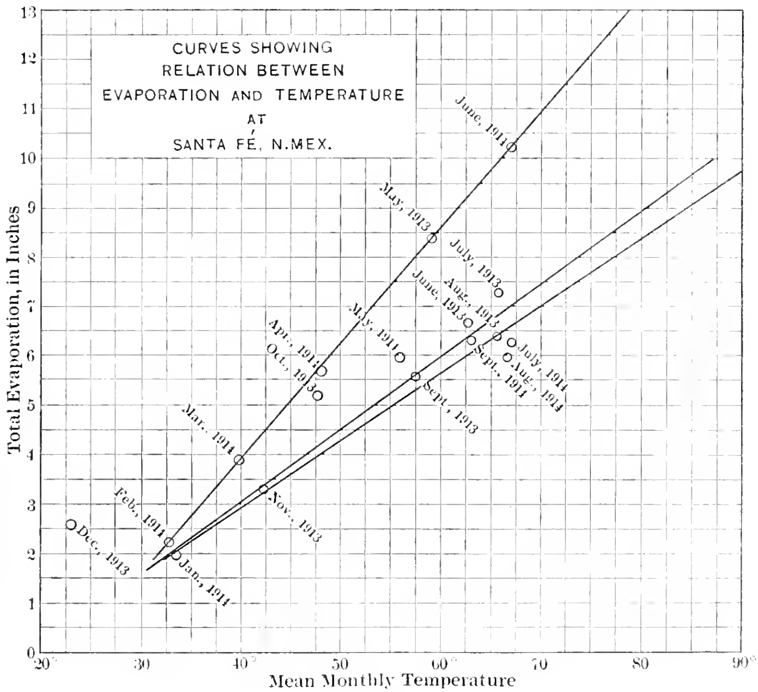

FIG. 21.

obtained. The points divide into two more or less distinct groups, one defining perfectly a line indicating evaporation nearly 30% greater than that shown by most of the remaining points. It is worth

Mr. Follansbee. noting that the points defining the line of higher evaporation represent spring months chiefly, when it would be expected that the evaporation for a given air temperature would be less on account of the lower temperature of the water. From these records, it is evident that other factors than temperature—such as wind velocity and relative humidity—influence evaporation to such an extent in the upper part of the Rio Grande drainage that it is impossible to determine evaporation with any degree of accuracy from temperature records alone.

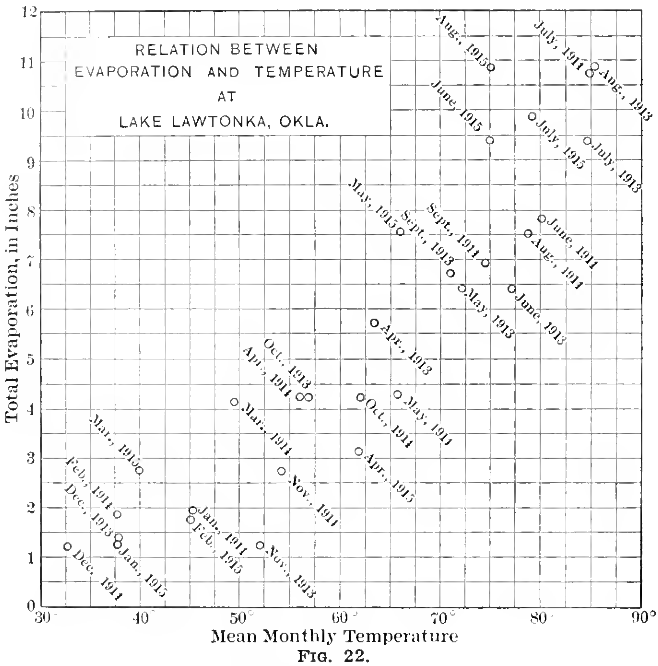

FIG. 22.

An investigation of evaporation records in the southwestern part of Oklahoma was made in order to determine whether a simple relation obtained between temperature and evaporation in that section of the country. These records, which are compiled by the U. S. Geological Survey, are from a standard pan, 3 ft. square and 18 in. deep, floating on the surface of Lake Lawtonka, 14 miles northwest of Lawton, at an elevation of about 1 200 ft.

Table 64 shows the records.*

It may be stated that, owing to the wave action on Lake Lawtonka, it has been found necessary to shorten the upright needle by which the evaporation is measured, so that the water surface in the pan is about 7 in. below the top.

* Published chiefly in *Water Supply Papers Nos. 357 and 387.*

Mr. Follansbee.

TABLE 64.—TOTAL EVAPORATION NEAR LAWTON, OKLA.

Month.	1913.		1914.		1915.	
	Evaporation, in inches.	Temperature* of air.	Evaporation, in inches.	Temperature* of air.	Evaporation, in inches.	Temperature* of air.
Jan.	......	......	1.94	45.6	1.39	38.0
Feb.	......	......	1.88	37.8	1.77	45.2
Mar.	......	......	4.13	49.5	2.71	40.5
Apr.	5.74	63.1	4.24	56.8	3.15	62.0
May	6.45	72.2	4.31	65.6	7.56	66.3
June	6.43	77.1	7.84	80.2	9.44	75.2
July	9.43	84.6	10.79	84.3	9.90	79.0
Aug.	10.92	85.8	7.56	78.8	......	......
Sept.	6.73	71.2	6.96	74.7	......	......
Oct.	4.24	57.0	4.28	62.0	......	......
Nov.	1.24	52.0	2.72	54.2	......	......
Dec.	1.25	38.2	1.21	33.1	.....	......

* Mean monthly temperature recorded by Weather Bureau at Lawton, 14 miles distant.

The plotting of the monthly evaporation and mean air temperature, Fig. 22, shows that the relation between the two at this point is complicated to a great extent by the other evaporation factors, making it impossible to determine evaporation from air temperatures alone.

Mr. Jorgensen.

L. R. JORGENSEN,* M. AM. SOC. C. E. (by letter).—In this valuable paper the authors, in their estimate of evaporation depths from lake surfaces, have laid great stress on the influence of mean temperature and relative elevations. They mention other influences, but consider them of less importance. This reasoning no doubt is sound, and holds true for Lake Conchos and similar cases.

The writer, however, desires to call attention to what in his judgment is a different case, and where the greatest stress will have to be laid on the influence of prevailing winds and the extreme dryness of the air.

It became of value to know the evaporation depths of Grant and Silver Lakes, in Mono County, Eastern California, in order to decide on the economy of developing both, or only one, of them, for storage purposes, and to find out how much water was available for irrigation purposes after allowance had been made for the losses. No evaporation data were on hand from the lakes themselves, but the yearly evaporation depths from a few points approximately 100 miles distant were known, and these data had to be interpolated to fit Silver Lake conditions.

The writer had been on the ground during the three hottest Summer months, and during this time observed two things which were especially kept in mind when reasoning out the probable yearly evapora-

* San Francisco, Cal.

Mr. Jorgensen.

tion depth from these lakes. These two things were the extreme dryness of the atmosphere, and the prevailing daily "trade" winds. Silver Lake is at Elevation 7 212, in a narrow canyon, from 1 500 to 3 000 ft. deep. There are extensive deserts about 8 miles north and east of the lake, and a few miles to the west the crest of the Sierra Nevada Mountains is always covered with snow. This condition creates the "trade" winds, the direction of which is down the canyon during the greater part of the day, and up the canyon after dark. This last condition may be due in part to the peculiar bend of Reversed Creek, from which it derives its name.

The rate of evaporation naturally depends on the ability of the air near the water surface to absorb water. The avidity with which air absorbs water increases as the humidity of the air decreases. If the humidity of the air is high, it will evaporate but little water, no matter what the temperature may be; and if the temperature of the humid air is much higher than that of the water, the water will soon cool the air in contact with it to such an extent that it can absorb no water at all, because it has reached its dewpoint at this new temperature. At such a stage the lake has been covered with an effective "vapor blanket".

The conditions at Silver Lake are such as to induce evaporation as much as possible. The humidity is very low, and therefore the air in contact with the lake surface absorbs moisture quickly. Whatever vapor blanket tends to form is destroyed periodically by the wind, which brings new air in contact with the water surface. The temperature is fairly high during the summer; there is no rain during this time of maximum evaporation, and therefore this evaporation takes place every day. The two features at this place which tend to keep down evaporation are the high elevation, and the regular oval shape of the lake.

Through such reasoning, and from the data at hand,* it was estimated that the yearly gross evaporation from Silver Lake would be 4 ft. 6 in. This is probably high, considering the fact that the lake is frozen over in the winter, but, if so, it is on the safe side. It was also known that the irrigation duty of the water used in the valley below these lakes at practically the same elevation was 7 acre-ft. This high value is not due to heavy evaporation entirely, however, but partly to the porous character of the soil.

At Lake Conchos, fortunately, the rainy season coincides with the season of maximum temperature, and this condition undoubtedly tends to keep down evaporation loss; otherwise one would expect the yearly evaporation depths there to be higher than 55 in., due to the high average temperature and the very irregular shape of the lake.

* *Water Supply Paper No. 68,* and a pamphlet from the Truckee-Carson Experiment Farm.

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PAPERS AND DISCUSSIONS

CHEMI-HYDROMETRY AND ITS APPLICATION TO THE PRECISE TESTING OF HYDRO-ELECTRIC GENERATORS

Discussion.*

By G. Bertram Kershaw, M. Am. Soc. C. E.

G. Bertram Kershaw,† M. Am. Soc. C. E. (by letter).—The writer has read Mr. Groat's paper with great interest. With respect to the word, "Chemi-hydrometry", as the author points out, this is a hybrid word derived from the Latin and Greek languages. As salt alone is used for mixing with the water, the writer would suggest the word, halo-hydrometry, derived from the Greek word 'ἁλς (hals) meaning salt. We already have the term, isohales, or lines of equal salinity, derived from 'ἴσος (equal) and 'ἁλς (salt). Halo-hydraulics would not be suitable, as the word 'αὐλος signifies a pipe. Mr. Kershaw.

Will Mr. Groat kindly explain briefly the "moving-screen" method of measuring large volumes of flowing water, mentioned on page 2104.‡ The writer would also like to know whether the salt caused any appreciable frothing of the water when passing through the turbines, and whether there was any tendency of the meters to "short-circuit"?

Has Mr. Groat tried the use of coloring matter in the water in lieu of salt, for example, fluorescin, and does he consider a colorimetric method feasible?

* This discussion (of the paper by Benjamin F. Groat, M. Am. Soc. C. E., published in November, 1915, *Proceedings*, and presented at the meeting of December 15th, 1915), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† Westminster, S. W., London, England.

‡ *Proceedings*, Am. Soc. C. E., for November, 1915.

Mr. Kershaw.

With regard to the "shaking of samples", mentioned on page 2258,* it was found necessary, during the taking of some thousands of samples of sewage, tank liquor, and effluent, to adopt a uniform method in order to secure a fairly complete mixture. The individual sample bottles were filled absolutely full, avoiding air bubbles as far as practicable. Actual shaking was found to be far less effective than quietly inverting each bottle for about 5 sec., and then reversing it, the operation being repeated ten times in succession. The absence of an air bubble in this case lengthened the period required for satisfactory mixing.

The writer would be much obliged if Mr. Groat would give the names of the makers of the Ott and Haskell meters; he has used the small Price meter for many years, and has found it to be a most excellent instrument. He has also used the Ekman meter, which is provided with an ingenious compass arrangement whereby the angle made by the head of the meter with magnetic north can be ascertained at great depths. Generally speaking, current meters manufactured in England leave much to be desired.

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* *Proceedings*, Am. Soc. C. E., for November, 1915.

MEMOIRS OF DECEASED MEMBERS.

Note.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

CHARLES ABBOTT LOCKE, M. Am. Soc. C. E.*

Died November 12th, 1915.

Charles Abbott Locke was born at La Grange, Tenn., on December 25th, 1841. Like many Southern boys in ante-bellum days, his early training was under a tutor, but he studied engineering later at the Presbyterian Synodical College in La Grange, receiving his diploma in 1861, after he had enlisted in the Southern Army as a private. His studies at college were under the personal direction of Professor J. L. Meigs.

In December, 1861, he joined the Seventh Tennessee Confederate Cavalry (Forest's Brigade). He surrendered and was paroled at Gainesville, Ala., on May 10th, 1865. He was captured near Atlanta in 1864 and taken to Winchester, Tenn., where he made his escape, crossing the mountains on foot, swimming the Tennessee River, and finally, after many hardships and narrow escapes in traversing the enemy's country, he rejoined his command. After the War, he joined his old Professor and friend, Col. Meigs, who was then Chief Engineer of the Memphis and Charleston Railroad, and served under him as Assistant on this road and also on the Memphis and Little Rock Railroad.

In 1867 Mr. Locke was married to Miss Virginia Beck, of Covington, Ga., and until 1873 was engaged in the milling business in West Tennessee.

In 1873 we find him at Memphis as Locating and Division Engineer on the Paducah and Memphis Railroad; here he had cholera, which undermined his health. He returned to Georgia and took charge of the physical survey of that State.

In 1878 he became Assistant United States Engineer in charge of improvements on the Oconee and Ocmulgee Rivers, and, later, on the Tennessee River below Florence, Ala., Muscle Shoals Canal, Cumberland and Tennessee Rivers, and their tributaries.

In 1889 he assisted in organizing the Engineering Association of the South.

In 1890, while living in Nashville, Tenn., he left the Government service and engaged in private practice.

Mr. Locke was interested in geological research, and spent much of his time in economic geological studies, especially in connection with

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* Memoir prepared by Hunter McDonald, Past-President, Am. Soc. C. E., and E. C. Lewis and W. F. Foster, Members, Am. Soc. C. E., a Committee of the Engineering Association of the South.

the phosphate industries in the Southern States. Later, he also made studies and investigations for a prominent Eastern Portland Cement Manufacturing Syndicate headed by Robert W. Lesley, Assoc. Am. Soc. C. E. Mr. Locke possessed a rare instinct for this kind of work, and his careful, painstaking efforts made his reports of great value to his clients. He was fond of mechanics also, and spent much of his leisure hours in working in metals in his shop at home. He loved Nature, and preferred to study it alone, making long excursions into the wilds of Canada in search of the small-mouth bass, the fighting proclivities of which he prized very highly. Though he had had a checkered and gallant career as a soldier, he was unlike many men in that he never talked of his war record, and it was with great difficulty that even his best friends were able to draw him into a conversation regarding these adventures. Fit by birth, nature, ability, and education to fill high official positions, he served the entire four years of the war as a private soldier.

He was a man of delicate physique, but of large and strong mental and moral force. He possessed high ideals, and was the soul of honor and integrity; he was unselfishly devoted and faithful to his friends, of whom he had many; a student of public affairs, and a severe critic of the acts of public men, he contributed often to the local press, always over his own signature, and to appreciative readers. He had the courage of his convictions and principles, and asserted them through his ballot at the polls.

At the time of his death, and for many years previous thereto, Mr. Locke was an active and useful member of the Committee in charge of the Tennessee Confederate Soldiers' Home, where his knowledge of engineering was of great value.

The last act of his life was one of unselfish devotion to a friend, and his effort to shield him was the immediate cause of his death.

He died of heart failure in Nashville, Tenn., on November 12th, 1915. His wife and his daughter, Mrs. J. G. Kirkpatrick, a widow, both living at Nashville, survive him.

Mr. Locke was elected a Member of the American Society of Civil Engineers on October 3d, 1888.

OLAF RIDLEY PIHL, M. Am. Soc. C. E.*

Died October 14th, 1915.

Olaf Ridley Pihl, the eldest son of Carl Abraham and Catherine (Ridley) Pihl, was born in Christiania, Norway, on January 9th, 1855. His father was the pioneer railroad engineer of Norway, and had received his first instruction in England. When the Norwegian

* Memoir prepared by Emile Low, M. Am. Soc. C. E.

Government built its first railroad, Mr. Robert Stephenson, a son of the more celebrated George Stephenson, was in charge of this work, and the elder Mr. Pihl became one of his principal assistants. When the work was completed, Mr. Pihl became Chief Engineer and thereafter spent almost his entire life in the railroad service of the Norwegian Government. He became known as the father of the narrow-gauge railroad, and was frequently consulted as an authority on that system, which, at one time, had many advocates who considered the 3-ft. or 3½-ft. gauge as the most suitable and economical under many conditions. In the Seventies, he was invited to Canada as the guest of honor at the opening of several narrow-gauge railroads radiating northward from Toronto.

His brother, Olaf Pihl, was also one of the leading civil engineers of Norway, having been engaged mainly in municipal engineering, and was the first to introduce gas-works in that country. A younger brother, Einar Pihl, came to the United States in 1879, and served in the United States Engineer Office at Portland, Ore., on the Columbia River jetties. He died of typhoid fever in Portland, in 1886. The celebrated Antarctic explorer, Einar Borchgrevink, the first man to winter on the Antarctic Continent, was a cousin of Olaf Ridley Pihl, on his mother's side.

The home of Olaf Ridley Pihl's father in Christiania was one of the most enlightened and interesting in the capital of Norway. It was a great meeting place for the leading and aggressive men of science and the developing Profession of Engineering, who would gather about the fireplace of the library on winter evenings discussing and listening to live questions propounded and debated by the leading spirits of the country, as well as by men of prominence of other countries, who were fortunate in being guests at this hospitable home. The elder Mr. Pihl was a member of scientific societies and received many distinctions, such as orders of knighthood, from rulers of various countries.

Olaf Ridley Pihl's mother, Catherine Ridley, a refined and accomplished English lady, was a lineal descendant of Bishop Nicolas Ridley.

Mr. Pihl's boyhood was spent in Christiania, and he received his technical education at Chalmers Polytechnical College (Chalmarska Institut), in Gothenburg, Sweden, from which he was graduated in 1876 with the degree of civil and mechanical engineer.

During his college years and the four years after his graduation—from 1876 to 1880—he was employed in the Norwegian Government service as Second and afterward as First Assistant Engineer on the survey of the Western Railroad, from Christiania to Laurvik.

Due to his father's Canadian trip, Mr. Pihl chose Canada as a field of action, and, provided with letters of introduction to his father's friends, left Norway in 1880 for Toronto, Ont., Canada, in company with two of his college classmates, Mr. A. L. Hertzberg, now Division Engineer of the Canadian Pacific Railroad, and S. M. Kielland, M. Am. Soc. C. E., now Chief Engineer of the Buffalo Creek Railroad, and Norwegian Consul at Buffalo, N. Y.

The party, however, did not stop in Canada, but proceeded to Portland, Ore., where Mr. Pihl secured service with the Oregon Railway and Navigation Company as Topographer and, later, as Resident Engineer on construction, remaining with this railroad from 1880 to 1884. From 1884 to 1887, he was Engineer for Hoffman and Bates, Bridge Builders, of Portland, Ore.

In 1887, he entered the service of the Federal Government in the United States Engineer Office, at Portland, Ore., as Assistant Engineer in charge of the construction of the canal and locks at the Cascades of the Columbia River in Oregon. While in this service, he designed a boat railway scheme for overcoming the obstructions in the Columbia River between The Dalles and Celilo Falls, for which a canal and locks were finally adopted. He was also engaged on the jetty work at Yaquina Bay, and made several surveys and examinations for work in the Portland District. In 1898 he severed his connection with that office and removed to Buffalo, N. Y. During this period, he was engaged in contracting work for a short time.

After his arrival in Buffalo, Mr. Pihl received an appointment as U. S. Assistant Engineer from Major (now Colonel) T. W. Symons, Corps of Engineers, U. S. A. (Retired), in charge of the reconstruction of a portion of the Buffalo Breakwater.

In 1900, he accepted service with the Pan-American Exposition as Designing Engineer, which position he resigned to become a member of the firm of Edward J. Hingston and Olaf R. Pihl, for building the coffer-dam, foundation, piers, and abutment for a movable dam and guide cribs, and erecting Chanoine wickets, at Herr Island Lock and Dam in the Allegheny River, all under the direction of the U. S. Engineer Office at Pittsburgh, Pa.

During 1901-04, Mr. Pihl was associated with the Dravo Construction Company, as Secretary and as Engineer in charge of design and field work.

In 1905 he was taken into the firm of Cadwallader and Robinson, Contracting Engineers, of Pittsburgh, Pa. During his connection with this firm, they built the masonry arches at Lashel and Stoops Ferry for the Pittsburgh and Lake Erie Railroad, a power-house for the Pittsburgh Division of the Pennsylvania Railroad, a freight-house for the Allegheny Division of the same railroad, and double-tracked a portion of the Youngwood Branch.

On April 1st, 1906, Mr. Pihl formed a partnership with Mr. W. B. Miller, under the firm name of Pihl and Miller, Contracting Engineers, with offices in the Wabash Building, Pittsburgh, Pa. He continued with this firm until his death. During this time he completed no less than 300 contracts with railroad companies and leading steel plants in the Pittsburgh District. Mr. Pihl was particularly interested in water intake work, and designed and built some of the best plants in that section.

It has already been noted that he came from a very excellent home which left a lasting impression on him and shaped his personality. He was a gentleman in the best meaning of the word, in his tastes, and in the selection of his friends. To those only superficially acquainted with him, he appeared to be distant; to his friends, he was as true as gold and most considerate and courteous.

In addition to his ability as a constructive engineer, Mr. Pihl developed amateur photography to a very high artistic degree. Though he would never consent to make public exhibition of his efforts, his nearest friends had the pleasure of seeing much of his masterly work which was beautiful both in feeling and execution.

He did not relish service under others—in other words, he did not like to be a subordinate—and had the courage to strike out for himself as an engineer and contractor. Too few engineers possess this faculty, the lack of which keeps them from securing independence and financial success.

His chief characteristic as a contractor was to make his work of the first quality (cost not being considered); and he would not countenance or employ any but honest and capable men. He was quick to see the good in a man, and as quick to see his weakness. He was the most generous of men, and would help in any charity he considered deserving.

Mr. Pihl was energetic and progressive in constructive ideas, being well-grounded in the knowledge of theoretical engineering. He was a man of principle, and was not afraid to stand up for his convictions; whatever he undertook was accomplished in a thorough and conscientious manner. Taken as a whole, he was a true, honorable man. His friends will remember him with respect and reverence.

In August, 1904, Mr. Pihl was married, in New York City, to Sofie Christine Mellbye, of Christiania, Norway, who, with two daughters, survives him. He is also survived by his mother, six sisters, and a brother, who live in Norway.

Mr. Pihl died suddenly on October 14th, 1915, of heart failure on his way from his home to his office. He looked very strong and apparently was in excellent health. His body was cremated and his ashes were taken to Norway by his widow, to be laid at rest in the family burying ground in Christiania.

Mr. Pihl was elected a Member of the American Society of Civil Engineers on October 2d, 1889.

MORTON LOUDON TOWER, M. Am. Soc. C. E.*

Died April 17th, 1915.

Morton Loudon Tower was born at Boston, Mass., on January 5th, 1870. He was the only son of Major Morton Tower and Annie Mason Loudon Tower, who, in 1874, moved to the Pacific Coast and settled at Empire, Ore. Through his father, he was a direct lineal descendant of John Alden and Priscilla Mullins who landed from the *Mayflower* at Plymouth in 1620. His father was a Major of Volunteers in the Civil War, and, subsequent to his removal to the Pacific Coast, was for many years Collector of Customs at Coos Bay, Ore. His maternal grandfather, Thomas Loudon, of Glasgow, Scotland, and, later, of Liverpool, England, was a mechanical engineer, inventor, and iron-maker, and helped construct and place the engines in the first steamer built by the Cunard Line to cross the Atlantic.

Mr. Tower attended the public schools of Oregon. With the exception of a few months of special instruction at the University of California in 1888, his well-balanced technical knowledge was acquired in the school of experience and by extensive reading. In his sixteenth year, he began to acquire engineering experience on surveys. From March, 1889, his employment on engineering works was practically continuous; and from March, 1891, until his death in April, 1915—24 years—his service was with the Corps of Engineers, United States Army.

Prior to his entry into the Government service, he was, from November, 1886, to August, 1887, Rodman and Chainman with Mr. N. P. Granger, of San Fernando, Cal.; March to November, 1889, General Field Assistant with Lucas Brothers, Bridge Engineers; from January to June, 1890, Chainman and Rodman, Coos Bay, Roseburg, and Eastern Railway; and from June, 1890, to March, 1891, Transitman, Topographer, Sextant Observer, Leveler, etc., with Mr. A. J. McMillan.

In the Government service, the works to which Mr. Tower was assigned were varied. From March, 1891, to November, 1901, as Junior Engineer, most of the time in local charge of works, he was engaged on river surveys and on dredging and the construction of jetties. He designed and constructed a combined dredge and snagboat and operated it on the Coquille River and in Coos and Tillamook Bays, Oregon. From November, 1901, to July, 1905, he was engaged on hydrographic surveys of, and projects for improving, several Pacific Coast harbors and rivers in Oregon and Washington, among which were Tillamook and Coos Bays, Columbia, Siuslaw, Umpqua, and

* Memoir prepared by H. H. Wadsworth, M. Am. Soc. C. E., and Lee S. Griswold, Assoc. M. Am. Soc. C. E., a Committee of the San Francisco Association of Members of the American Society of Civil Engineers.

Coquille Rivers, Oregon, and Lewis River, Washington. On jetty construction and fortification at the entrance to the Columbia River, he served under G. B. Hegardt, M. Am. Soc. C. E., at Fort Stevens. At the entrance to Coos Bay, Coquille River, and Siuslaw River, he was in local charge of jetty construction.

In July, 1905, at the instance of Colonel (then Captain) William W. Harts, M. Am. Soc. C. E., Corps of Engineers, U. S. Army, Mr. Tower was transferred to San Francisco for duty under the California Débris Commission. He made surveys of some of the tributaries of the Sacramento River, which were surcharged with débris (mining tailings) resulting from early extensive hydraulic mining operations, and prepared plans for restraining further movement of the débris into navigable waters. He also inspected many hydraulic mines and reported on the restraining works to be prescribed by the Commission for construction by operators prior to the issuance of licenses for mining.

In January, 1907, Colonel (then Major) C. H. McKinstry, M. Am. Soc. C. E., a member of the California Débris Commission, and also Engineer Officer in charge of lighthouse construction in the San Francisco District and of the fortifications of San Francisco Harbor, secured the services of Mr. Tower as Superintendent in the Lighthouse Department. While on that duty, he made surveys of lighthouse sites and designed foundations for light stations. From February, 1908, to August, 1910, he was in local charge of construction and of other field work at Forts Baker, Barry, McDowell, Scott, Miley, and Mason, San Francisco Harbor, except the period from August to December, 1908, when he was assigned to duty at Honolulu, Hawaii, in charge of harbor dredging.

From September, 1910, until his death, Mr. Tower had charge of the construction of the jetties at the entrance to Humboldt Bay, California. Humboldt Bay, on which is situated the City of Eureka, is the most important harbor between San Francisco Bay and the mouth of the Columbia River. The maintenance of safe depths across Humboldt Bar has been difficult and expensive, frequent severe storms having repeatedly beaten down the jetty enrockment and carried away the trestle used for its construction. Mr. Tower conceived the idea of concreting the top surface of the rock jetty as fast as it was raised to grade, and of anchoring the construction track in the concrete, using specially designed traveling derricks to handle the construction materials. This method of construction has proved highly successful.

On Thursday, April 15th, 1915, while proceeding with Lieut.-Col. Thomas H. Rees, Corps of Engineers, U. S. Army, and two other men, to inspect the quarry from which rock was secured for the jetty, the motor track car on which they were traveling jumped the track on a trestle and precipitated the passengers some 15 or 20 ft. down into a gulch among boulders. The accident was witnessed by some of the quarrymen, and the injured men were speedily conveyed to a hospital at Eureka. Two of the men escaped with comparatively slight injuries, Col. Rees suffered a broken leg, but Mr. Tower had three ribs broken and was otherwise internally injured, and died two days later. As emblems of mourning, and of the esteem in which he was held at Eureka, the flags of the Federal and other public buildings, and on the bay shipping generally, were placed at half mast. He was buried at Marshfield, Ore.

Mr. Tower was married at San Francisco, Cal., on November 16th, 1894, to Cornelia Maud Armes Smith, who, with three daughters, Gladys Fredricka, Ella Gwynedde, and Cornelia Morton, survives him.

He was a man of most genial disposition, delighting greatly in associating with his friends, of whom he had many, and with his fellow engineers. He contributed a paper on bar harbors on the coast of Oregon,* as well as a discussion on a paper on concrete piles,† to the *Transactions* of the Society.

Mr. Tower was elected an Associate Member of the American Society of Civil Engineers, on May 6th, 1908, and a Member on July 1st, 1909. He was also a member of the Benevolent Protective Order of Elks, Eureka Lodge, No. 652.

CHARLES DOD WARD, M. Am. Soc. C. E.‡

Died July 30th, 1915.

Charles Dod Ward was born on March 15th, 1838, in Williamsburg (Brooklyn), N. Y. He was the son of John Dod Ward and Laura M. Roburds. His father began his career as a machinist, and, by his ability and industry, succeeded in becoming the proprietor of several large iron works and foundries. He was one of the owners of the famous Novelty Iron Works, of New York, and later established the Atlas Foundry, of Jersey City. He took a lively interest in obtaining for New York City a good water supply, and was twice appointed by the Governor of the State a member of the Board of Water Commissioners, under whose direction the Old Croton Water-Works were constructed. Later, he became President of the Commission which built the water-works of Jersey City. Charles Dod Ward, as well as his older brothers John F. Ward, the inventor of the flexible joint for water mains, and the late Lebbeus B. Ward, M. Am. Soc. C. E., inherited from their father a talent for engineering.

* "Notes on the Bar Harbors at the Entrances to Coos Bay and Umpqua and Siuslaw Rivers, Oregon", *Transactions,* Am. Soc. C. E., Vol. LXXI, p. 349.

† "Concrete Piles", by Howard J. Cole, M. Am. Soc. C. E., *Transactions,* Am. Soc. C. E., Vol. LXV, p. 488.

‡ Memoir prepared by Edward Wegmann, M. Am. Soc. C. E.

Until his sixteenth year Charles Dod Ward attended the Lyceum School in Jersey City. From this school, he went into the Atlas Foundry, owned by his father, to obtain some practical knowledge of foundry work and machinery, but continued his studies for four years under private tutors. Unfortunately, he had attacks of pneumonia during three successive springs, and was advised by his doctors to leave the foundry and lead an outdoor life, as much as possible. In accordance with this advice, he spent two years on farms belonging to a relative and to a friend, taking an active part in the farm work.

Having recovered his health, Mr. Ward decided to become a civil engineer. For two or three years he assisted Mr. Garret J. Van Horne, a well-known civil engineer, of Jersey City, and he also did some work on the Morris Canal in New Jersey.

In his subsequent career, Mr. Ward located and built a great many miles of railroad, and was also engaged on the construction of important water-works. From 1862 to 1865, he made surveys in the State of New York for an extension of the Harlem Railroad, for a railroad from Catskill to Schenectady, and for one from Rondout to Ellensville. In 1866 he was engaged on the location of the Ulster and Delaware Railroad, and soon afterward located part of the Susquehanna and Delaware Railroad, under the late Julius W. Adams, Past-President, Am. Soc. C. E., Chief Engineer.

From 1867 to 1869, Mr. Ward was in charge of the construction of the extension of the Utica and Black River Railroad, and then located and had charge of the construction of the Western Division of the New Haven, Middletown, and Willimantic Railroad (New York and Boston Air Line) to December, 1870.

At the request of the late I. C. Buckhout, M. Am. Soc. C. E., Chief Engineer of the Harlem Railroad, Mr. Ward took charge, in 1872, of the surveys for an underground railroad in New York City from the City Hall to the Grand Central Station, which the late Commodore Vanderbilt proposed to build. Complete plans and estimates were made for this project, but it was abandoned on account of the cost involved.

In 1876 and 1877, Mr. Ward was Chief Engineer of a branch railroad in Connecticut from Colchester to the New York and Boston Air Line. Subsequently, he was engaged for about a year on the construction of the Metropolitan Elevated Railroad on Sixth Avenue, New York City. During 1881, he located parts of the T. C. and St. Louis Railroad. In 1886, he was engaged by F. C. Curtis, Chief Engineer of the New York, New Haven, and Hartford Railroad, to make a re-survey of that line in Connecticut from Middletown to Willimantic, with the view of making improvements in the alignment and grades.

Mr. Ward began his experience on water-works in 1866 under the late James P. Kirkwood, Past-President, Am. Soc. C. E., whom he assisted in preparing plans for enlarging the water-works of Cincinnati, Ohio. He was soon afterward engaged for a short time on the water-works of New York under Alfred Craven, M. Am. Soc. C. E., Chief Engineer. In 1871 and part of 1872, he was Principal Assistant Engineer, under the late J. Herbert Shedd, M. Am. Soc. C. E., Chief Engineer, on the water-works of Providence, R. I.

During 1873, he made surveys for the North Hudson Water Commission, of New Jersey, and, in 1883, he was engaged on surveys and plans for the New Jersey Water Supply Commission. From 1889 to 1911, he was heavily interested in the Portsmouth and Suffolk Water-Works, of Virginia, on which he acted as Engineer and in other official capacities. From November, 1894, to May 1st, 1910, Mr. Ward was engaged on the maintenance and extension of the Brooklyn Water-Works, on which he had charge of many important improvements. He resigned his position on account of ill-health, and practically retired from the active pursuit of engineering; but he maintained his interest in the Profession, and occupied his time in studying important engineering problems. One of these was the proposed improvement of the East River at Hell Gate; Mr. Ward proposed a plan for this work, which had considerable merit and was indorsed by a number of persons interested in navigation, to whom it was submitted.

He made two extensive trips abroad. In December, 1874, with a party of friends, he visited Palestine, Egypt, Mount Sinai, Petra, and the east side of the Dead Sea, and traveled much in Europe. His second trip lasted from June, 1878, to December, 1879, and extended from the Mediterranean to the North Cape of Norway and from England to Moscow, Russia.

In 1880, the late Ashbel Welch, Past-President, Am. Soc. C. E., and Mr. Ward were examining a relief map of the proposed route of the Panama Canal, and Mr. Ward suggested that a dam should be built at Gatun. At that time neither of these engineers knew that M. Godin Lepinay had made the same recommendation at the International Congress of Surveys for an Interoceanic Canal, held at Paris, France, in 1879. In discussing the paper by the late A. G. Menocal, M. Am. Soc. C. E., entitled "Inter-Oceanic Canal Projects", in April, 1880,* Mr. Welch stated:

"The first thought of an American canal and river engineer, on looking at M. de Lesseps' raised map, is to convert the valley of the lower Chagres into an artificial lake, some 20 miles long, by a dam across the valley at or near the point where the proposed canal strikes it a few miles from Colon, such as was advocated by Mr. C. D. Ward."

* *Transactions*, Am. Soc. C. E., Vol. IX, p. 148.

In 1904 Mr. Ward read before the Society a paper on the Gatun Dam,* in connection with the Panama Canal. The Isthmian Commission of 1899 had selected Bohio as the site for a dam to be constructed across the Chagres River. Mr. Ward pointed out in his paper the great advantages that would be derived by building the proposed dam some 10 miles farther down stream at Gatun. He suggested, also, the construction of a dam at La Boca, at the Pacific end of the Canal.

The late Alfred Noble, Past-President, Am. Soc. C. E., a member of the Board of Consulting Engineers appointed in 1905 to report on the plans that should be adopted for the Panama Canal, said, in a letter dated April 18th, 1907, about Mr. Ward's paper on the Gatun Dam:

"The Ward paper created so deep an impression among engineers that one of the earlier examinations made by the First Construction Commission appointed by President Roosevelt was to determine by means of boring the depth to rock and the nature of the overlying earth along the line of the proposed dam. The earth was found to extend to such a depth that the construction of a masonry dam was found to be impracticable, and the project for a dam of this kind was too hastily set aside. There were many, however, who believed with Mr. Ward that a perfectly safe and satisfactory dam could be made of earth, and that the advantages of the location from the point of view of navigation were so obvious that the subject was not allowed to drop, and it received favorable consideration from the minority of the Board of Consulting Engineers in 1905.

"While it is possible to say that the Gatun location would not have been adopted had Mr. Ward's paper not been written, the fact that the first suggestion to this end was dropped and remained unheeded, except by him, for more than twenty years, and that its revival was due to him exclusively, make it most probable that, but for his persistent efforts, the excellent plan of Canal now adopted would not have developed, and either an inferior lock plan or a far more costly sea level plan would have been adopted."

Mr. Ward's paper on the Gatun Dam was presented to the Board of Consulting Engineers of the Panama Canal of 1905, by which Board it was duly considered and ordered reprinted in full in the Appendix of its Report. Both the dams advocated by Mr. Ward have been built, and the cost of the Canal has thereby been much reduced. Although his paper had undoubtedly much to do with the selection of the sites for these two dams, Mr. Ward never received any proper recognition for the great service he had performed by his recommendations therein relative to the Gatun Dam.

As an engineer, he had excellent judgment, both in the location of public works and in their construction, which was greatly appreciated by his superiors. He was exceedingly modest and retiring, and this disposition may have interfered, at times, with his obtaining

* *Transactions,* Am. Soc. C. E., Vol. LIII, p. 36.

proper recognition. All those who enjoyed his friendship felt the charm of his fine mind and sterling character.

Mr. Ward was married on December 6th, 1882, to Ada Davey, daughter of Henry L. Davis, of Oswego, N. Y., and widow of William Augustus Davey, of Jersey City, N. J. He is survived by his wife and by a daughter, Mrs. Gerald Stuart O'Loughlin. A second daughter—Mary Frances—died in 1889.

Mr. Ward was elected a Member of the American Society of Civil Engineers on March 3d, 1869.

WILLIAM FREDERICK ALLEN, Assoc. M. Am. Soc. C. E.*

DIED NOVEMBER 9TH, 1915.

William Frederick Allen was born in Bordentown, N. J., on October 9th, 1846, the son of Col. Joseph Warner Allen and Sarah Burns (Norcross) Allen. On the paternal side the family is of English origin. Samuel Allen, the founder of the American line, came from Chew Magna, near Bristol, England, in 1681, and settled in the Colony of Pennsylvania, at Bridgewater, near Bristol. Mr. Allen's father was a civil engineer, and had charge of many water-power developments and railway enterprises. At the beginning of the Civil War he was Deputy Quartermaster-General of New Jersey and, later, raised the 9th Regiment, New Jersey Volunteers, of which he was Colonel. He served under Gen. Burnside in the North Carolina expedition, and met his death by drowning off Cape Hatteras, on January 15th, 1862.

Mr. Allen was educated at the Bordentown Model School and at the Protestant Episcopal Academy in Philadelphia. His engineering experience began in 1862, as Rodman with the Engineer Corps of the Camden and Amboy Railroad. In the following year he became Assistant Engineer. In 1868 he was transferred to the West Jersey Railroad as Resident Engineer, in which capacity he served nearly five years. At this period (1870), he founded and laid out the Town of Wenonah, N. J. In October, 1872, he became Assistant Editor of the *Official Railway Guide*, and six months later was made Editor and Manager of the National Railway Publication Company, of which he was elected Vice-President in 1910 and President in 1914.

Some idea of the enormous growth of the *Official Railway Guide*, published by this Company, which contains complete time-tables, accurately corrected to date every month, of all the railways of the United States, Canada, and Mexico, may be gathered from the fact that when Mr. Allen took charge in 1872, it had only 192 pages, but has

* Memoir prepared by Charles A. Hammond, M. Am. Soc. C. E.

now increased to more than 1 600 pages, and is the largest monthly publication in the world. It is admirably arranged and indexed for ready reference, containing an authorized and complete list of railway officers forming the managing staff of each railroad company, also railway maps, mileage operated, editorials, official news, and other information of value to the railway public. It is in use the country over as the standard reference authority in the transportation service.

In addition to his duties connected with the National Railway Publication Company, Mr. Allen had been Secretary of the American Railway Association and its predecessors since April, 1875, when he was appointed Secretary of the General Time Convention, and in October, 1877, of the Southern Time Convention. In April, 1886, these organizations were consolidated to form the American Railway Association, and Mr. Allen continued as Secretary, becoming, in June, 1909, its General Secretary and Treasurer, which positions he held until his death.

The membership of the American Railway Association is composed of the railroad companies in the United States, Canada, and Mexico, operating 300 000 miles of railway. The object of the Association is the recommendation of methods for the management and operation of American railways. It has perfected the "Standard Code of Train Rules, Block Signal Rules and Interlocking Rules"; the improvement of Car Service Methods, including the Code of Per Diem Rules looking to increasing the efficient distribution of freight cars; a National Code of Car Demurrage Rules, to facilitate the prompt movement of freight cars; Standard Track Scale Specifications and Rules, and Uniform Rules for the Weighing and Re-weighing of Carload Freight; the adoption of Standard Heights for Draw-bars, also of Standard Dimensions for Box Cars and for Rail Sections; and a Bureau for the Safe Transportation of Explosives.

In his capacity as Secretary of the Association, Mr. Allen became intimately acquainted with a large number of railway managers. The Presidency of the Association has been held successively by different men, from different parts of the country, but the Secretaryship has been a permanent feature, and his administration of the office has been an important element in the Association's prosperity, contributing in no small degree to the remarkable success of its efforts in standardizing and improving American railway practice.

Undoubtedly, Mr. Allen's greatest claim to a world's gratitude is his monumental achievement in the establishment of the present system of "Standard Time". In 1881, the General Time Convention referred to him for solution the difficult problem of working out a standard of time reckoning that would obviate the confusion resulting from the use of the fifty or more local-time standards then prevailing in the United States. His report was submitted in 1883. His plan divided the country into five even-hour zones, based on the quadrant meridian (90° west of Greenwich) and the meridians of each 15° east and west of it. The report also provided for an elastic boundary line between the hour zones, instead of a strictly longitudinal division, and in its details fixed every point at which the hour-change was to be made, worked out the method of passing, without confusion, from one hour-standard to the other, adjusted the difference between local and standard time, and embodied every practical provision for placing the system in immediate effect. The report was unanimously endorsed by the Association, and Mr. Allen was empowered to secure its adoption by the railways. In this work, he had the co-operation of the Cambridge and the National Observatories.

The change in the operating time-tables of the many different railroads throughout the country was made at noon, eastern time, on Sunday, November 18th, 1883, without delay or disturbance. For this splendid achievement, pronounced one of the greatest in the history of transportation, Mr. Allen was elected to Honorary Membership in many American and foreign scientific societies, and received, in 1906, from Princeton University, the honorary degree of Master of Science.

The American system of standard time, as devised by Mr. Allen, and successfully inaugurated through his untiring efforts and special facilities for reaching and influencing the railway managements of the country and other interests involved, has now been adopted by all the nations of Europe, by Japan, and by the South American countries—practically by all the civilized nations of the world.

Mr. Allen was a delegate of the United States Government to the International Meridian Conference in 1884, and to the International Railway Congress at Paris in 1900. He was a delegate of the American Railway Association to the International Railway Congresses at London, 1895; Paris, 1900; Washington, 1905; and Berne, 1910. Since 1910, he had been a member of the Permanent Commission of the Congress Association. In 1905, he had charge of all the arrangements for the session of that year at Washington, which was presided over by Mr. Stuyvesant Fish, and considered one of the most successful meetings in the history of the organization. At this session Mr. Allen was Associate Secretary-General. For his services at the Washington session of the Congress, he received from the Belgian Government the decoration of Chevalier of the Order of Leopold.

Mr. Allen was also greatly interested in efforts to establish the metric system in the United States, and was Chairman of the Committee of the American Railway Association on this subject.

The prodigious and versatile activity of this remarkable man may be appreciated when we remember his affiliation with many different organizations in the railway, scientific, business, and social world. Besides being President of the National Railway Publication Company, and of the Knickerbocker Guide Company, he was Vice-President of the New York Transfer Company, and a Director in numerous other corporations; a member of the Geographical Society of Vienna, Austria; Geographical Society of Lima, Peru; American Geographical Society; National Geographic Society; American Metrological Society; American Academy of Political and Social Science; American Statistical Association; American Economic Society; American Association for the Advancement of Science; American Forestry Association; American Railway Guild, of which he was a Past Master and principal founder; Loyal Legion; New Jersey Historical Society; Washington Academy of Sciences; the New England Society of Orange, N. J., of which he was ex-Counsellor; and the Pennsylvania Society of New York.

Mr. Allen had resided at South Orange, N. J., since 1881, and had taken an active part in the development of that residential community, serving on the Drainage Commission to straighten the Rahway River, and on the Board of Trustees of the Village. He was Warden and, for many years, a Vestryman of the Church of the Holy Communion in South Orange. He was also a member of Century Lodge and a Trustee of the South Orange Free Public Library.

On Sunday, November 21st, 1915, a public meeting was held in Columbia School Hall, South Orange, to express the appreciation of the citizens of the village for Mr. Allen's public work, as a citizen as a friend, and as a neighbor. More than 600 were in attendance, and addresses were made by Spencer Miller, M. Am. Soc. C. E., Member of the Naval Advisory Board; Edward D. Duffield, Ex-Assistant Attorney-General, State of New Jersey; and Wilson Farrand, Headmaster, Newark Academy.

In 1889, with his associates, Mr. Allen organized and became President of the Meadow Land Society, with the object of preserving the beauty of the valley in the center of South Orange Village, and of providing facilities for field sports. The Society acquired the large tract of land which made possible the fine grounds of the South Orange Field Club, of which organization he was also a charter member, and for many years one of the Board of Governors, and President. A part of the ground formerly owned by the Meadow Land Society is now Cameron Field, and, in the creation of this public playground, Mr. Allen was also an active participant and one of the Trustees. In 1908, he was a delegate of the Eighth New Jersey Congressional District to the National Republican Convention in Chicago.

His clubs include the Railroad and the Traffic Clubs of New York;

the South Orange Field and South Orange Republican Clubs, of South Orange, N. J., of both of which he had been President; and the Essex County Country Club.

Mr. Allen was married on April 20th, 1871, to Caroline Perry Yorke, daughter of Hon. Thomas Jones Yorke, of Salem, N. J., who survives him, together with four sons—all graduates of Princeton University—Yorke Allen, a lawyer of New York City, Frederick Warner Allen, connected with the banking firm of Wood, Struthers and Company, of New York, Eugene Yorke Allen, Assoc. M. Am. Soc. C. E., Civil Engineer with the Central Railroad of New Jersey, and John Sinnickson Allen, Secretary of the Gamewell Fire Alarm Telegraph Company.

Mr. Allen was one of the most lovable of men. His intercourse with his fellows was always marked by kindness, sincerity, and a beautiful courtesy. Energy, faithfulness, and a conscientious discharge of duty were his prominent characteristics, and the editorial pages of the *Guide* reveal his fine and discriminating intellect. The burden of his multifarious activities and responsibilities was borne with such grace and apparent ease, that few realized the strain it must have been, until Nature at length gave way. It was while motoring to witness the Princeton-Harvard football game, on Saturday, November 6th, that he suffered an apoplectic attack, becoming unconscious before home could be reached, and lingering painlessly in that condition until his death on Tuesday, November 9th. The funeral services, held in the church he loved so well, were attended by a large number of railroad men, for whom a special train had been furnished by the Delaware, Lackawanna and Western Railway Company.

Mr. Allen had made all his preparations for attending the fall meeting of the American Railway Association, held in Chicago, on November 17th, 1915, at which meeting the following action was taken:

"In Memory of William Frederick Allen

"Secretary of The American Railway Association from the date of its organization, April, 1886, to November 9th, 1915; General Secretary and Treasurer from June, 1909, to November 9th, 1915; Secretary of the General Time Convention from April, 1875, and Secretary of the Southern Railway Time Convention from October, 1877, until their consolidation in 1886, at which time The American Railway Association was created; originator of the idea of Standard Time, which has been universally adopted.

"Mr. Allen's industry and loyal co-operation with his associates during a period of forty years were always most helpful and welcome to them, and they record with profound sorrow his death at his home in South Orange, New Jersey, on the afternoon of November 9th, 1915, in the seventieth year of his age.

"His great ability, high character, and forceful and amiable personality endeared him to all who knew him, and inspired their admiration, friendship, and esteem. In his death the Association has lost an able and resourceful officer, and his friends and associates deeply mourn the loss of a friend and counsellor.

"*Resolved*, That this tribute to his memory be inscribed on the minutes of this Association, and that an engrossed copy be delivered to his family, to whom The American Railway Association tenders its sympathy in their great sorrow."

Mr. Allen was elected an Associate Member of the American Society of Civil Engineers on January 3d, 1909.

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"A STUDY OF THE BEHAVIOR OF RAPID SAND FILTERS SUBJECTED TO THE HIGH-VELOCITY METHOD OF WASHING." JOSEPH W. ELLMS and JOHN S. GETTRUST. (To be presented Mar. 1st, 1916.)

"THE EFFECTS OF STRAINING STRUCTURAL STEEL AND WROUGHT IRON." HENRY S. PRICHARD. (To be presented Mar. 1st, 1916.)

PAPERS AND DISCUSSIONS CURRENT IN PROCEEDINGS

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Discussion (Author's Closure.)......Nov., Dec., 1914, Jan., Feb., Mar., Apr., May, Aug., Sept., Oct., Nov., 1915, Jan., 1916

"**Suggested Changes and Extension of the United States Weather Bureau Service in California.**" GEORGE S. BINCKLEY and CHARLES H. LEE......Feb., 1915
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"**The Twelfth Street Trafficway Viaduct, Kansas City, Missouri.**" E. E. HOWARD.......May, "
Discussion.......Sept., Oct., Nov., "

"**Pearl Harbor Dry Dock.**" H. R. STANFORD.......May, "
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"**The Action of Water Under Dams.**" J. B. T. COLMAN.......Aug., 1915
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"**Concrete-Lined Oil-Storage Reservoirs in California: Construction Methods and Cost Data.**" E. D. COLE.......Aug., "
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"**The Astoria Tunnel Under the East River for Gas Distribution in New York City.**" JOHN VIPOND DAVIES.......Aug., 1915
Discussion (Author's Closure.).......Nov., Dec., 1915, Jan., 1916

"**Induced Currents of Fluids.**" F. ZUR NEDDEN.......Aug., 1915
Discussion.......Nov., Dec., "

"**The Hydraulic Jump, in Open-Channel Flow at High Velocity.**" KARL R. KENNISON.......Sept., "
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"**A Study of the Depth of Annual Evaporation from Lake Conchos, Mexico.**" EDWIN DURYEA, JR., and H. L. HAEHL.......Sept., 1915
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"**The Automatic Volumeter.**" E. G. HOPSON.......Oct., 1915
Discussion.......Dec., "

"**The Cherry Street Bridge, Toledo, Ohio.**" CLEMENT E. CHASE.......Oct., "
Discussion.......Dec., "

"**Chemi-Hydrometry and Its Application to the Precise Testing of Hydro-Electric Generators.**" BENJAMIN F. GROAT.......Nov., "
Discussion.......Jan., 1916

"**The Economical Top Width of Non-Overflow Dams.**" WILLIAM P. CREAGER...Nov., 1915

"**The Failure and Righting of a Million-Bushel Grain Elevator.**" ALEXANDER ALLAIRE. (To be presented Feb. 2d, 1916.).......Dec., "

"**A Review of the Report of Captain Andrew Talcott, Chief Engineer, Mexico and Pacific Railroad, Eastern Division, from Vera Cruz to City of Mexico: Explorations, Surveys, Estimates.**" EMILE LOW.......Dec., "

"**Cohesion in Earth: The Need for Comprehensive Experimentation to Determine the Coefficients of Cohesion.**" WILLIAM CAIN. (To be presented Feb. 2d, 1916.).......Dec., "

Progress Report of the Special Committee on Materials for Road Construction and on Standards for Their Test and Use.......Dec., "

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Progress Report of the Special Committee on Steel Columns and Struts.....Dec., "

Progress Report of the Special Committee on Floods and Flood Prevention..Dec., "

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

VOL. XLII—No. 2

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PROCEEDINGS

OF THE

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OF

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(INSTITUTED 1852)

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FEBRUARY, 1916

Edited by the Secretary, under the direction of the Committee on Publications.

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MINUTES OF MEETINGS

OF THE SOCIETY

SIXTY-THIRD ANNUAL MEETING*

January 19th, 1916.—The meeting was called to order at 10 A. M.; President Charles D. Marx in the chair; Charles Warren Hunt, Secretary; and present, also, about 500 members.

The Annual Report of the Board of Direction, and the Annual Reports of the Secretary and of the Treasurer,† for the year ending December 31st, 1915, were presented and accepted.

* A full report of the Sixty-third Annual Meeting is printed on pages 80 to 117 of this number of *Proceedings*.

† For these reports, see pages 13 to 23 of *Proceedings* for January, 1916 (Vol. XLII).

The Secretary read the report of the Committee appointed by the Board of Direction to recommend the award of prizes,* and announced that the Medals and Prizes for the year ending July, 1915, had been awarded by the Board of Direction in conformity with that report, as follows:

THE NORMAN MEDAL to Paper No. 1308, entitled "Storage to be Provided in Impounding Reservoirs for Municipal Water Supply", by Allen Hazen, M. Am. Soc. C. E.

THE J. JAMES R. CROES MEDAL to Paper No. 1304, entitled "Measurement of the Flow of Streams by Approved Forms of Weirs with New Formulas and Diagrams", by Richard R. Lyman, Assoc. M. Am. Soc. C. E.

THE THOMAS FITCH ROWLAND PRIZE to Paper No. 1292, entitled "Modern Pier Construction in New York Harbor", by Charles W. Staniford, M. Am. Soc. C. E.

THE JAMES LAURIE PRIZE to Paper No. 1291, entitled "Coal Piers on the Atlantic Seaboard", by J. E. Greiner, M. Am. Soc. C. E.

THE COLLINGWOOD PRIZE FOR JUNIORS to Paper No. 1281, entitled "Colorado River Siphon", by George Schobinger, Jun. Am. Soc. C. E. (now Assoc. M. Am. Soc. C. E.).

The Secretary presented the report of the Tellers appointed by the Board of Direction to canvass the suggestions as to members of the Nominating Committee, and the following were appointed to serve two years:

E. J. FORT....................	*Representing*	*District*	*No.*	*1.*
S. E. TINKHAM...............	"	"	"	*2.*
F. W. CAPPELEN...............	"	"	"	*3.*
H. H. QUIMBY................	"	"	"	*4.*
E. N. LAYFIELD...............	"	"	"	*5.*
W. B. GREGORY...............	"	"	"	*6.*
J. B. C. LOCKWOOD.............				

W. W. Crosby, M. Am. Soc. C. E., Chairman of the Special Commitee on Materials for Road Construction and Standards for Their Test and Use, presented a Progress Report of that Committee.†

On motion, duly seconded, the matter of enlarging both the membership and the scope of the Special Committee on Road Materials was referred to the Board of Direction.

Gardner S. Williams, M. Am. Soc. C. E., at the request of F. H. Newell, M. Am. Soc. C. E., Chairman of the Special Committee on A National Water Law, presented a Progress Report of that Committee.‡

The report was accepted.

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* See page 80.

† Printed on pages 2721 to 2746 of Papers and Discussions in the *Proceedings* for December, 1915.

‡ Printed on pages 2747 to 2751 of Papers and Discussions in the *Proceedings* for December, 1915.

The Progress Reports of the Special Committee on Steel Columns and Struts* and of the Special Committee on Floods and Flood Prevention† were accepted.

On motion, duly seconded, the Special Committee on Floods and Flood Prevention was continued for the purpose of joining with the Special Committee on A National Water Law.

The Secretary reported that he had received a discussion on the report of the Special Committee on Floods and Flood Prevention; and was authorized to print it in *Proceedings.*

J. R. Worcester, M. Am. Soc. C. E., Chairman of the Special Committee on Concrete and Reinforced Concrete, reported that the Committee had no report to present, but was preparing its final report, and hoped to present it prior to July 1st, 1916.

This was accepted as a Progress Report.

Desmond FitzGerald, Past-President, Am. Soc. C. E., Chairman of the Special Committee on Engineering Education, reported progress, and Professor C. R. Mann addressed the meeting on that subject.

The Committee was continued.

Leonard Metcalf, M. Am. Soc. C. E., Secretary of the Special Committee on Valuation of Public Utilities, on behalf of Frederic P. Stearns, Past-President, Am. Soc. C. E., Chairman of that Committee, submitted a Progress Report.

The report was accepted.

The report of the Special Committee to Investigate the Conditions of Employment of, and Compensation of, Civil Engineers was called for, and the Secretary stated that the Committee was preparing a complete report and expected to submit it at the Annual Convention.

This was accepted as a Progress Report.

Robert A. Cummings, M. Am. Soc. C. E., Chairman of the Special Committee to Codify Present Practice on the Bearing Value of Soils for Foundations, presented a Progress Report.‡

The report was accepted.

A. N. Talbot, M. Am. Soc. C. E., Chairman of the Special Committee to Report on Stresses in Railroad Track, presented a Progress Report.§

The report was accepted.

R. S. Buck, M. Am. Soc. C. E., presented a resolution to the effect that it is the sense of the meeting that the Army and Navy establishments of the Government should be enlarged and that the industrial and transportation resources of the country should be mobilized.

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* Printed on pages 2753 to 2769 of Papers and Discussions in the *Proceedings* for December, 1915.

† Printed on pages 2771 to 2787 of Papers and Discussions in the *Proceedings* for December, 1915.

‡ This report will be printed in the *Proceedings* for March, 1916.

§ See page 103.

On motion, duly seconded, the meeting declared its sympathy and general approval of the principles set forth in the resolution as offered by Mr. Buck, and that the Board of Direction be instructed to consider to-day and prepare a suitable expression of those ideas, to be transmitted to the American Security Congress to-morrow, through the Committee of this Society on National Preparedness.

The Secretary announced the election of the following candidates on December 6th, 1915:

As Members

Samuel Eben Barney, New Haven, Conn.
George Washington Bishop, Newtonville, Mass.
Charles Clefford Jacobs, Amboy, Ill.
Fred Atwood Jones, Dallas, Tex.
Paul Nash, Stamford, Conn.
Petrus Wahlman, New York City

As Associate Members

Lewis Penn Bailey, Legaspi, Philippine Islands
Ernest Wood Baldwin, Balboa, Canal Zone, Panama
Herbert Bartholomew, Pedro Miguel, Canal Zone, Panama
Roswell Spencer Baylis, Huntington, N. Y.
John Wilson Bell, Carlsbad, N. Mex.
Clarence Earl Blee, San Francisco, Cal.
Charles Norton Boult, Westport, New Zealand
Evlane Kemper Carter, Liberty, Mo.
William Clark Cattell, Wenonah, N. J.
John William Cerny, Denver, Colo.
Elga Ross Chamblin, Dallas, Tex.
Norman Butler Conway, Yuma, Ariz.
Arthur Daniels, Milwaukee, Wis.
William Clarence Davidson, Waco, Tex.
Thomas Henry Dennis, Colusa, Cal.
George Garrett Edwards, Ennis, Tex.
Frederic Elwin Everett, Concord, N. H.
Frederic Morris Faude, San Diego, Cal.
Harry Franklin Flynn, Seattle, Wash.
William Norman Hall, Brownsville, Tex.
Fletcher Ames Hatch, Atlantic, Mass.
Beauford Emmett Hayden, Newell, S. Dak.
Frederick Ruthrauff Hoover, Kansas City, Mo.
Charles Thomas Jackson, Glasgow, Mo.
Henry Louis Jacques, Milpitas, Cal.
John Frank Jasienski, Lakewood, Ohio
Louis Raub Johnson, San Diego, Cal.

Irving Patterson Kane, Detroit, Mich.
Robert Newell Kinnaird, Des Moines, Iowa
George Leslie Kirby, Toledo, Ohio
Claude Milton Lambe, Raleigh, N. C.
Victor Lieb, Elephant Butte, N. Mex.
Hallett Edward McClintock, Omaha, Nebr.
Dana Quick McComb, New York City
John Frederic Mangold, Grinnell, Iowa
Horatio Seymour Mattimore, Albany, N. Y.
Clyde Leo Miller, Youngstown, Ohio
Robert Gaston North, Pittsfield, Mass.
Harry Neale O'Brien, Baltimore, Md.
George Henry Reussner, Malta, Mont.
Stanley Rush Sharts, Dayton, Ohio
Burr Henry Simpson, Cambridge, Ohio
Harvey Stanley, Boca Grande, Fla.
Arthur Leon Strong, Mt. Vernon, Wash.
Paul McGeorge Trueblood, Manila, Philippine Islands
Raymond Verner Warren, Pittsburgh, Pa.
Everitt Wyche Wilson, Ancon, Canal Zone, Panama
Dana Melvin Wood, Boston, Mass.

As Juniors

Matthew Laurence Carey, New York City
Alden Knowlton Fogg, Champaign, Ill.
Pedro Garcia, Lima, Peru
George Foden Rooking Hall, London, England
Jacob Joseph, Brooklyn, N. Y.
Jesse Lowe, Jr., Beardstown, Ill.
Emil Praeger, Brooklyn, N. Y.
Roger Bradshaw Quincy, New Orleans, La.
Spottiswoode Wellford Randolph, Chicago, Ill.
Walter Alan Richards, Catawba, N. C.
Arthur Ruettgers, Ann Arbor, Mich.
Reuben Benjamin Sleight, Denver, Colo.
William Glenn Sloan, Boise, Idaho.
Russell Alger Van Ness, McLean, Ill.
Adam Cooper Warfel, Philadelphia, Pa.
James McBarron Webster, New York City

The Secretary announced the transfer of the following candidates on December 6th, 1915:

From Junior to Associate Member

Ned Duncan Baker, Tientsin, China
Carl Donald Bossert, Washingtonville, Ohio

Fred Drexel Bowlus, San Fernando, Cal.
Daniel Elias Davis, Pittsburgh, Pa.
Carl E. Downing, Belzoni, Miss.
Joseph Jay Durfee, Brooklyn, N. Y.
Charles Sumner Henning, Jr., El Paso, Tex.
Richard Irvin, Pittsburgh, Pa.
Charles Christopher Kilby, New Haven, Conn.
Manley Osgood, Ann Arbor, Mich.
Joseph Price, Buffalo, N. Y.
Paul Francis Rossell, Wilmington, Del.
Walter Vanderbelt Scott, Buffalo, N. Y.
Charles Henry Shapleigh, New Orleans, La.
Lawrence Vinnedge Sheridan, New York City
Francis Marshall Smith, Pasco, Wash.
Everett Harold Swett, Montrose, Colo.
William Sidney Tomlinson, Columbia, S. C.
Alvin Dumond Wilder, Berkeley, Cal.

The Secretary announced the election of the following candidates on January 17th, 1916:

As Associate Members

Arthur Engh, Chicago, Ill.
Julian Clarence Feild, Denison, Tex.
Orlando Henry Frick, Milwaukee, Wis.
Albert Benedict Gidley, Marshfield, Ore.
John Owen Greenway, Sunnyside, Wash.
Seizo Hattori, Omuta, Fukuokaken, Japan
Lewis Stirling Hereford, Lake Charles, La.
Benjamin Alfred Howes, New York City
Roswell Sears Lander, Chattanooga, Tenn.
Charles Dix McArthur, Pittsburgh, Pa.
Archibald E. Palen, Denver, Colo.
William Copeland Pickersgill, Providence, R. I.
Royal Elmer Post, Meadow Creek, Wash.
Fred Dale Pyle, Montrose, Colo.
Alfred Emmet Roche, Troy, N. Y.
William Checkley Shaw, Jr., Seabrook, S. C.
Benjamin Single Thayer, La Mesa, N. Mex.
George Furbush Whittemore, Eureka, Cal.
Norman Cooper Woody, Minneapolis, Minn.

As Juniors

Albert Edward Broker, Milwaukee, Wis.
William Owen Cotton, Idaho Falls, Idaho
Alfred Michael Danzilli, Pittsburgh, Pa.
Ewing Sloan Humphreys, New York City
Harrison Aubrey Underwood, Durham, N. C.

The Secretary announced the transfer of the following candidates on January 17th and 18th, 1916:

From Associate Member to Member

Elliot Chipman Brown, New York City
Edgar Stone Closson, Montclair, N. J.
Clarke Peleg Collins, Johnstown, Pa.
Stephen Truesdell De La Mater, Chicago, Ill.
Homer Munro Derr, Pierre, S. Dak.
Llewellyn Nathaniel Edwards, Toronto, Ont., Canada
Squire Earnest Fitch, Westfield, N. Y.
Roy Cotsworth Gowdy, Fort Worth, Tex.
Julius Reed Hall, Oak Park, Ill.
Leroy Lemoyne Hidinger, Memphis, Tenn.
Granville Johnson, Boston, Mass.
Arthur Herman Markwart, San Francisco, Cal.
Alfred Boardman Mayhew, Dayton, Ohio
Arthur Tappan North, Chicago, Ill.
Vincent Phillip Odoni, Tucson, Ariz.
Irwin Selden Osborn, Toronto, Ont., Canada
Harry Harwood Rousseau, Balboa Heights, Canal Zone, Panama
Robert Lemuel Sackett, Lafayette, Ind.
Morton Franklin Sanborn, Albany, N. Y.
John Lucian Savage, Boise, Idaho
Norton Ware, San Francisco, Cal.

From Junior to Associate Member

Richard Mansfield Merriman, Central Valley, N. Y.

The Secretary announced the following deaths:

William W. Follett, of El Paso, Tex., elected Member, July 5th, 1893; died December 30th, 1915.

Charles Conrad Schneider, of Philadelphia, Pa., elected Member, February 6th, 1884; Director, 1887; 1898-1900; Vice-President, 1902-1903; President, 1905; died January 8th, 1916.

James Knapp Wilkes, of New Rochelle, N. Y., elected Associate Member, June 3d, 1891; Member, April 3d, 1906; died January 9th, 1916.

David Williams, of St. Johnsbury, Vt., elected Member, May 4th, 1898; died November 27th, 1915.

Loren Edward Hunt, of San Francisco, Cal., elected Associate Member, June 3d, 1903; died January 9th, 1916.

Ludlow Victor Clark, of Philadelphia, Pa., elected Associate, October 4th, 1892; died December 28th, 1915.

The Secretary announced that the Board of Direction had decided that the next Annual Convention of the Society would be held in Pittsburgh, Pa., from June 27th to 30th, inclusive, and that a Local Committee of Arrangements had been appointed consisting of Messrs. George S. Davison, J. A. Atwood, R. A. Cummings, Richard Khuen, Morris Knowles, D. W. McNaugher, Emil Swensson, E. B. Taylor, W. G. Wilkins, and Paul L. Wolfel.

The Secretary presented the report of the Tellers appointed previously by the Board of Direction to canvass the Ballot for Officers for the ensuing year.

The President announced the election of the following officers:

President, to serve one year:

Elmer L. Corthell, New York City

Vice-Presidents, to serve two years:

Alfred Craven, New York City

Palmer C. Ricketts, Troy, N. Y.

Treasurer, to serve one year:

Lincoln Bush, New York City

Directors, to serve three years:

Virgil G. Bogue, New York City
Alexander C. Humphreys, New York City
Otis F. Clapp, Providence, R. I.
Richard Khuen, Pittsburgh, Pa.
Frank G. Jonah, St. Louis, Mo.
Edwin Duryea, Jr., San Francisco, Cal.

On motion, duly seconded, a vote of thanks was tendered to the Tellers for their work.

Hunter McDonald, Past-President, Am. Soc. C. E., conducted Mr. Corthell to the chair.

Mr. Corthell addressed the meeting briefly.

Adjourned.

SPECIAL MEETINGS FOR THE DISCUSSION OF THE PROGRESS REPORT OF THE SPECIAL COMMITTEE ON MATERIALS FOR ROAD CONSTRUCTION

January 21st, 1916.—The meeting was called to order at 10.30 A. M.; W. W. Crosby, M. Am. Soc. C. E., Chairman of the Special Committee on Materials for Road Construction, in the chair; A. H. Blanchard, M. Am. Soc. C. E., acting as Secretary; and present, also, 147 members and guests.

The Chairman announced that the meeting had been called for the purpose of affording opportunity to discuss the Progress Report*

* Printed on pages 2721 to 2746 of Papers and Discussions in the *Proceedings* for December, 1915.

of the Special Committee on Materials for Road Construction and on Standards for Their Test and Use.

Written discussions by Messrs. P. E. Green and C. R. Mandigo were read by the Secretary. The report was then discussed orally by Messrs. H. S. Mattimore, W. M. Kinney, A. H. Blanchard, J. H. MacDonald, T. J. McGovern, Edward D. Reed, R. A. Meeker, A. N. Johnson, K. H. Talbot, J. C. Bentley, P. H. Wilson, George C. Warren, E. H. Thomes, and H. B. Drowne.

Adjourned.

January 21st, 1916.—The meeting was called to order at 2.20 P. M.; W. W. Crosby in the chair; A. H. Blanchard acting as Secretary; and present, also, 147 members and guests.

The discussion of the Report of the Special Committee on Materials for Road Construction was continued by Messrs. Prévost Hubbard, T. J. McGovern, E. H. Thomes, William H. Connell, William C. Perkins, A. H. Blanchard, J. W. Howard, J. T. Myers, H. B. Drowne, W. W. Crosby, H. W. Durham, R. A. MacGregor, and W. B. Greenough.

Adjourned.

REGULAR MEETING

February 2d, 1916.—The meeting was called to order at 8.30 P. M.; P. K. Yates, M. Am. Soc. C. E., in the chair; Chas. Warren Hunt, Secretary; and present, also, 113 members and 18 guests.

The minutes of the meetings of December 15th, 1915, and January 5th, 1916, were approved as printed in *Proceedings* for January, 1916.

A paper by Alexander Allaire, M. Am. Soc. C. E., entitled "The Failure and Righting of a Million-Bushel Grain Elevator", was presented by the Secretary and discussed by Messrs. E. P. Goodrich and David Gutman.

A paper by William Cain, M. Am. Soc. C. E., entitled "Cohesion in Earth: The Need for Comprehensive Experimentation to Determine the Coefficients of Cohesion", was presented by the Secretary, who also read communications on the subject from Clifford Richardson, M. Am. Soc. C. E., and the author. The paper was discussed also by E. P. Goodrich, M. Am. Soc. C. E.

The Secretary read to the meeting a circular, which had just been issued, relating to the invitation of the United Engineering Society to join the American Institute of Mining Engineers, the American Society of Mechanical Engineers, and the American Institute of Electrical Engineers in the joint ownership and occupancy of their building on West Thirty-ninth Street.

The Secretary announced the following death:

Sledge Tatum, of Washington, D. C., elected Member January 4th, 1910; died January 18th, 1916.

Adjourned.

OF THE BOARD OF DIRECTION

(Abstract)

January 17th, 1916.—The Board met at 10 A. M.; President Marx in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Bontecou, Bush, Connor, Cooley, Crocker, Davies, Endicott, Fuller, Hodge, Herschel, Keefer, Leonard, Loweth, McDonald, Metcalf, Montfort, Ockerson, Swain, Tuttle, and Williams.

A report of the Board for the year 1915 was adopted for presentation to the Society.

A Budget covering the expenditures for 1916 was recommended to the incoming Board for adoption.

The Secretary reported that papers had been served on the Society by Nora Stanton Blatch asking the Supreme Court for a peremptory mandamus to force the Society, and its Board of Direction, to recognize her as an Associate Member; that counsel had been engaged, and an answer prepared with great care, because the question involved was as to whether the Society has the right to choose its own members. The action of the Secretary was approved, and he was instructed, in case of an adverse decision, to carry the matter to the higher Courts.

A report was received from the Committee to Recommend the Award of Prizes, and the prizes were awarded in accordance with the recommendation of the Committee.*

The incoming President was authorized to appoint a Committee of three to take up jointly with similar committees of other Engineering Societies all Legislative and Constitutional matters.

A Local Committee of Arrangements for the Annual Convention to be held at Pittsburgh was appointed.

The resignations of 11 Members, 31 Associate Members, and 19 Juniors were accepted.

Action was taken in regard to members in arrears for dues.

The report of the Tellers appointed by the Board to canvass the Final Suggestions for Members of the Nominating Committee was received and ordered presented to the Annual Meeting.

The Secretary reported that, in the absence of President Marx, he had been requested by a sub-committee of the Naval Consulting Board to meet with them, and with the Presidents of the National Societies of Mining, Mechanical, Electrical, and Chemical Engineers, to formulate a plan for securing the necessary data in regard to industrial plants throughout this country, with a view to preparedness in the manufacture of munitions of war; that such a plan had been formulated, and it is understood that President Wilson has approved it, and will ask each of the five Societies named to nominate one representative from each State, thus forming a Board of five in each State

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* See page 80.

who will become Associate Members of the Naval Advisory Board. Through these Boards, with the co-operation of the 35 000 members of the five organizations, it is expected that the necessary information will be secured promptly.

The incoming President of the Society was authorized to co-operate with the Naval Consulting Board in the manner specified.

Adjourned.

The Board reconvened at 3.55 P. M.; President Marx in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Bontecou, Bush, Connor, Cooley, Crocker, Davies, Endicott, Fuller, Harwood, Hawley, Hodge, Herschel, Keefer, Leonard, Loweth, McDonald, Metcalf, Montfort, Ockerson, Swain, Tuttle, and Williams.

A unanimous report was received from the Committee consisting of Clemens Herschel (Chairman), Robert Ridgway, Chas. Warren Hunt, Charles F. Loweth, John A. Ockerson, George F. Swain, and Hunter McDonald, which had been considering the offer made by the United Engineering Society that this Society join the American Institute of Mining Engineers, the American Society of Mechanical Engineers, and the American Institute of Electrical Engineers, in the joint ownership and occupancy of their building on West 39th Street.

This report, with such changes as may be necessary, was adopted as the report of the Board to the Society, and it was ordered to be sent out with a ballot.*

A report was presented by a Committee of the Board on the Licensing of Architects, etc., the recommendations of which were adopted. The report was ordered forwarded to the other three National Societies and to each of the Local Associations of this Society.†

Adjourned.

January 18th, 1916.—The Board met at 10.15 A. M.; President Marx in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Bontecou, Connor, Cooley, Crocker, Endicott, Greiner, Hawley, Herschel, Keefer, Loweth, McDonald, Metcalf, Montfort, Ockerson, Swain, and Williams.

A Report of Progress was received from William Barclay Parsons, Chairman of the Joint Committee on a Proposed Reserve Corps of Engineers.

A letter from the American Institute of Electrical Engineers was received suggesting that five members representing this Society be appointed to form with the other National Societies a Joint Committee to be known as the Pan-American Engineering Committee for the purpose of promoting a movement for a closer political, social, scientific,

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* See page 130.

† See page 140.

commercial, and industrial association throughout the Americas. The matter was referred to the incoming President with power.*

Adjourned.

The Board reconvened at 5 P. M.; President Marx in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Bontecou, Bush, Connor, Cooley, Crocker, Davies, Edwards, Endicott, Fuller, Greiner, Harwood, Hawley, Herschel, Keefer, Loweth, McDonald, Metcalf, Montfort, Ockerson, Swain, Tuttle, and Williams.

A report from the Membership Committee, which had been in session since the adjournment of the last Board meeting, was received and acted upon.

Ballots for membership were canvassed, resulting in the election of 6 Members, 67 Associate Members, and 21 Juniors, and the transfer of 20 Juniors to the grade of Associate Member.

Eighteen Associate Members were transferred to the grade of Member.

Applications were considered, and other routine business transacted.

Adjourned.

January 19th, 1916.—The Board met, as required by the Constitution, at the House of the Society, at 1.30 P. M., during the Annual Meeting, President Corthell in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Bogue, Bontecou, Bush, Clapp, Cooley, Craven, Crocker, Davies, Duryea, Endicott, Fuller, Greiner, Harwood, Haskell, Hawley, Herschel, Jonah, Keefer, Khuen, McDonald, Marx, Montfort, Ockerson, Swain, and Tuttle.

The President announced that the first business was the election of a Secretary.

Mr. Hunt retired.

Chas. Warren Hunt was nominated, and unanimously elected Secretary.

Mr. Hunt was recalled.

The following Standing Committees of the Board were appointed: Finance Committee: Clemens Herschel, Chairman, George W. Fuller, Alfred Craven, Otis F. Clapp, and F. G. Jonah; Publication Committee: Arthur S. Tuttle, Chairman, Virgil G. Bogue, Alex. C. Humphreys, J. E. Greiner, and J. F. Coleman; Library Committee: George A. Harwood, Chairman, J. V. Davies, H. S. Crocker, M. E. Cooley, and Chas. Warren Hunt.

The resolutions† offered by R. S. Buck, M. Am. Soc. C. E., at the Annual Meeting, and which were referred to the Board of Direction, were referred with power to a Committee consisting of Messrs. Corthell, Swain, and Hunt.

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* See page 142.

† See page 105.

The following motions were adopted:

"*Resolved:* That the meetings of the Board this year be held quarterly, the first to be held on the Tuesday before the third Wednesday in April (18th); the second to be held in Pittsburgh on the last two days of the week preceding the Annual Convention (June 23d-24th); the date of the third and fourth meetings to be determined later."

It was also determined that intermediate meetings of the Membership Committee and of the Board be authorized for the consideration of applications for admission and for transfer only.

Adjourned.

REPORT IN FULL OF THE SIXTY-THIRD ANNUAL MEETING, JANUARY 19TH AND 20TH, 1916.

Meeting called to order.

Wednesday, January 19th, 1916 (10 A. M.).—Charles D. Marx, President, in the chair; Charles Warren Hunt, Secretary; and present, also, about 500 members.

THE PRESIDENT.—The meeting will please come to order. We will now listen to the report of the Board of Direction, copies of which are being passed around at the present time. The Secretary will please read it.

Reports of the Board of Direction, Secretary, and Treasurer.

The Secretary presented the Report of the Board of Direction,* and the Report of the Secretary.†

THE PRESIDENT.—Is Mr. Bush here? If not, the Secretary will please read the Treasurer's report.

The Secretary read the Report of the Treasurer.‡

THE SECRETARY.—On the general balance sheet as printed in this pamphlet, gentlemen, there is a typographical error, a mistake of the printer. On the side headed "Assets", the estimated value of the three lots, the actual cost of which was $185 406.20, is given at $290 000, in accordance with the valuation made by the New York Real Estate Board. Then, instead of the word "Furniture", there should be "Building (cost, less 2% annually for depreciation), $130 621.59"; and then, "Furniture (cost, less 50% depreciation), $10 529.38". The rest of it is correct. I do not think it is necessary to read this statement.

THE PRESIDENT.—I do not think so. It is all before the Members.

A motion that the reports of the Board of Direction, the Secretary, and the Treasurer be received and placed on file is in order, and I will entertain such a motion.

GARDNER S. WILLIAMS, M. AM. SOC. C. E.—I so move.

(Motion duly seconded.)

THE PRESIDENT.—Those in favor of the motion say "aye"; contrary, "no". It is so ordered.

The next is the report of the Committee appointed to recommend the award of prizes for 1915.

Report of the Committee to Recommend the Award of Prizes.

THE SECRETARY.—The Board of Direction has received the following report from the Committee:

"TO THE BOARD OF DIRECTION
AMERICAN SOCIETY OF CIVIL ENGINEERS:

"The undersigned, a Committee appointed to Recommend the Award of Prizes for this year, beg leave to recommend the following awards:

"The Norman Medal to Allen Hazen, M. Am. Soc. C. E., for his paper entitled 'Storage to be Provided in Impounding Reservoirs for Municipal Water Supply'.

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* See *Proceedings*, Am. Soc. C. E., Vol. XLII, p. 13 (January, 1916).
† See *Proceedings*, Am. Soc. C. E., Vol. XLII, p. 20 (January, 1916).
‡ See *Proceedings*, Am. Soc. C. E., Vol. XLII, p. 23 (January, 1916).

"The J. James R. Croes Medal to Richard R. Lyman, Assoc. M. Am. Soc. C. E., for his paper entitled 'Measurement of the Flow of Streams by Approved Forms of Weirs with New Formulas and Diagrams'.

"The Thomas Fitch Rowland Prize to Charles W. Staniford, M. Am. Soc. C. E., for his paper entitled 'Modern Pier Construction in New York Harbor'.

"The James Laurie Prize to J. E. Greiner, M. Am. Soc. C. E., for his paper entitled 'Coal Piers on the Atlantic Seaboard'.

"The Collingwood Prize for Juniors to George Sehobinger, Assoc. M. Am. Soc. C. E., for his paper entitled 'Colorado River Siphon'.

"Respectfully submitted,

"DESMOND FITZGERALD,
WM. H. BURR,
GEORGE GIBBS,
"Committee."

And I have to report that the Board of Direction has awarded the medals and prizes in accordance with those recommendations.

Appointment of Nominating Committee.

THE PRESIDENT.—The next business is the report on members to serve on the Nominating Committee. You have the report of the Board on that?

THE SECRETARY.—Yes, sir. The Board, having canvassed the final suggestions received from the various districts, reports that there was a total of 1 670 suggestions received.

"District No. 1: Total suggestions received, 323, as follows:

E. J. Fort	215
E. P. Goodrich	77
J. F. Sanborn	18
Scattering	13"

There are two or three names of men who are ineligible, but I do not think it makes much difference. Shall we take them up by districts?

THE PRESIDENT.—I think so. The list of candidates in District No. 1 has been read, and a motion that some one be declared the representative of that district is now in order. Will some one make a motion with reference to District No. 1?

JOHN A. OCKERSON, PAST-PRESIDENT, AM. SOC. C. E.—I move that the gentleman who had the highest number of votes in District No. 1 be declared elected as member of the Nominating Committee.

THE SECRETARY.—E. J. Fort.

(Motion duly seconded.)

THE PRESIDENT.—Gentlemen, you have heard the motion. All who are in favor say "aye"; contrary, "no". It is so ordered.

Nominating Committee (continued).

THE SECRETARY.—"District No. 2: Total suggestions received, 202, as follows:

S. E. Tinkham	89
Frederic H. Fay	26
A. B. Hill	21
H. R. Safford	21
R. S. Lea	17
Henry Holgate	15
Scattering	13"

GEORGE F. SWAIN, PAST-PRESIDENT, AM. SOC. C. E.—Mr. President, I move that Mr. S. E. Tinkham be appointed a member of the Nominating Committee for District No. 2.

(Motion duly seconded.)

THE PRESIDENT.—Gentlemen, you have heard the motion. Those in favor of it say "aye"; contrary, "no". It is so ordered.

THE SECRETARY.—"District No. 3: Total suggestions received, 194, as follows:

W. R. Hill	71
F. W. Cappelen	70
Henry E. Riggs	31
W. L. Darling	11
Scattering	11"

A MEMBER.—I move that Mr. Hill be appointed a member of the Nominating Committee for District No. 3.

MR. WILLIAMS.—I wish to call attention to the fact that the present representative of the Nominating Committee who holds over is Mr. J. A. O'Connor, who is Terminal Engineer of the New York State Barge Canal. If Mr. Hill is selected to represent the district, it places two men, of the same organization, practically, on the Committee, and also two in the eastern end of the district. I would call attention to the fact that the retiring member of the Nominating Committee from this district is Professor F. E. Turneaure, of the University of Wisconsin.

In view of the fact that the votes cast—a large majority of them—came from the western end of the district, Mr. Riggs being a resident of Michigan, and Mr. Cappelen of Minnesota, and that Mr. Cappelen's vote is only one less than Mr. Hill's, I move that Mr. Cappelen be declared a member of the Nominating Committee from District No. 3.

(Motion seconded.)

HORACE ANDREWS, M. AM. SOC. C. E.—I think that the speaker is in error. Mr. O'Connor is no longer connected with the State service, but Mr. Hill is the President of the Albany Society of Civil Engineers, and is very well known to a large number here, and he has received the largest number of votes. Consequently, I think he ought to be considered for this position.

THE PRESIDENT.—The only motion is that made by Mr. Williams. The first motion was not seconded.

A MEMBER.—Will the Secretary give the number of the two highest.

THE PRESIDENT.—Certainly.

THE SECRETARY.—W. R. Hill has 71; F. W. Cappelen, 70.

THE PRESIDENT.—The motion before the meeting is on the election of Mr. Cappelen.

A MEMBER.—I desire to second the nomination of Mr. Hill, and to say that, notwithstanding the fact that you have already a member in the East, it would be unsafe to depart from the policy which we have pretty generally followed, of taking the opinion of the majority.

THE PRESIDENT.—Then your motion would be in the nature of an amendment to the original motion made by Mr. Williams?

A MEMBER.—I second the original motion.

A MEMBER.—I moved that Mr. Hill be the nominee, and a gentleman has seconded my motion, and I presume that is in order.

THE PRESIDENT.—I suppose the best thing to do would be to take a vote on the two candidates, and let the meeting decide it that way.

MR. WILLIAMS.—Allow me to say one word more, Mr. President, in response to the last speaker. We are not departing from a custom of this meeting in setting aside the result of the ballot. I would call attention again to the fact that Mr. Cappelen's votes numbered 70, and Mr. Riggs received 31. Mr. Hill received 71, and Mr. Darling 11. The majority of votes came from the western end of the district. The eastern end of the district has a member of the Nominating Committee. Now, I think that is unfair. I think that the members of the Society in the western end of the district are entitled to this representation. I have no objection to Mr. Hill, and I assume that his turn would come next year; but I cannot see that it is just to a district which extends from the Atlantic Ocean to the western boundary of Minnesota, to place two members in the northeastern corner of New York, and ignore the rest of the membership. I certainly hope that my motion will prevail.

THE PRESIDENT.—If there is no objection, I think we will take a vote on the two candidates, and I suggest that those in favor of the nomination of Mr. Cappelen please raise their right hands, and the Secretary will count the votes.

THE SECRETARY.—93.

THE PRESIDENT.—Those in favor of Mr. Hill's nomination please raise their right hands.

THE SECRETARY.—27.

Nominating Committee (continued).

The President.—In accordance with the vote, I declare Mr. Cappelen elected as representative of the Nominating Committee for District No. 3.

The Secretary.—"District No. 4: Total suggestions received, 240, as follows:

H. H. Quimby	137
M. J. Riggs	45
A. J. Himes	43
Scattering	15"

Richard L. Humphrey, M. Am. Soc. C. E.—Mr. President, I move that Mr. Quimby be appointed member of the Nominating Committee for District No. 4.

(Motion duly seconded.)

The President.—Gentlemen, those in favor of that motion please say "aye"; contrary, "no". It is so ordered.

The Secretary.—"District No. 5: Total suggestions received, 296, as follows:

E. M. Layfield	165
Baxter L. Brown	116
R. C. Barnett	9
Scattering	6"

Mr. Ockerson.—Mr. President, in the first round the southern contingent cast 90 votes, and the Chicago contingent, which was apparently asleep, cast only 12 votes. When they woke up from their normal lethargy, they got out and beat us; and I move that Mr. Layfield be declared a member of the Nominating Committee from District No. 5.

(Motion duly seconded.)

The President.—Gentlemen, you have heard the motion. All those in favor say "aye"; contrary, "no". It is carried.

The Secretary.—"District No. 6: Total suggestions received, 191, as follows:

W. B. Gregory	109
J. C. Nagle	34
B. M. Hall	19
T. U. Taylor	15
Scattering	14"

Hunter McDonald, Past-President, Am. Soc. C. E.—I move that Mr. Gregory be declared elected member of the Nominating Committee for District No. 6.

(Motion duly seconded.)

The President.—Gentlemen, you have heard the motion. Those in favor say "aye"; contrary, "no". It is carried.

THE SECRETARY.—"District No. 7: Total suggestions received, 224, as follows:

J. B. C. Lockwood	104
D. C. Henny	42
D. D. Clarke	34
Scattering	44"

THE PRESIDENT.—I will entertain a motion.

THE SECRETARY.—J. B. C. Lockwood is the top man.

A MEMBER.—I move that Mr. Lockwood be appointed member of the Nominating Committee for District No. 7.

(Motion duly seconded.)

THE PRESIDENT.—Those in favor of the motion signify by saying "aye"; contrary, "no". The motion is carried. It is so ordered.

Report of Committee on Materials for Road Construction.

The report of the Special Committee on Materials for Road Construction, Mr. W. W. Crosby, Chairman.

W. W. CROSBY, M. AM. SOC. C. E.—The Committee has prepared a semi-final report, and as it has been printed in *Proceedings** and is rather long and technical, I will not take the time of the meeting to read it, but will simply ask that the report be received, and that the Committee be continued, in order that it may complete its revision of its previous report, and then report in the near future.

THE PRESIDENT.—If there is no objection, it is so ordered.

E. W. STERN, M. AM. SOC. C. E.—On the question of road materials——

THE PRESIDENT.—Will you step up in front? I think the stenographer will get your words better.

Discussion on Committee on Materials for Road Construction.

MR. STERN.—The Special Committee on Materials for Road Construction and on Standards for their Test and Use has been in existence for quite a number of years—six or seven, I believe.

A year ago its functions were enlarged to deal with all road materials. The whole question of road construction, of course, as every one knows, is a most important one. One of the most important things before the country to-day, in engineering work, is the construction of roads and highways. To me the report just presented has been very disappointing. I believe it has been to others. Now, this great Society of ours should take some action in regard to this important thing, such as it has, for instance, in connection with reinforced concrete construction, where its recommendations were quite authoritative, and very beneficial, I believe.

A MEMBER.—It is a little difficult to hear what Mr. Stern has to say. Will he speak a little louder.

MR. STERN.—Now, in order to achieve results commensurate with the importance of this Society in the country, it would appear to me

* See *Proceedings,* Am. Soc. C. E., for December, 1915, pages 2721 to 2746 of Papers and Discussions.

Discussion on Committee on Materials for Road Construction (continued).

that the constitution of that Committee should be enlarged or changed so as to produce some results. So far, we have had recommendations on bituminous materials. The report this year, consisting of seven pages, is, as the Committee says, of the most general kind of recommendations. The Committee also seems to be under the impression that its scope is limited. I quote from its report:

"It should be distinctly understood that the Committee has deliberately refrained from including in this report such conclusions regarding any material or method as appear to have been generally agreed on."

I should like to ask why it deliberately refrained from giving us this valuable information, which not only we, but the entire country, is interested in.

The Committee, in its report, of course, calls attention to the pressure of other matters, which prevented a proper consideration of the criticisms or discussion offered. That is another argument, Mr. Chairman, why this Committee should be composed so that it can produce results. As it is to-day, the question of road building is taken up by other societies, none of them having the standing of this Society. All these societies are doing good work, but there still remains some body, a National body, that should act, and the position that we hold in the community is such that we should take this matter up and present strong recommendations.

This Society is in a position to do it. It must be done, however, by the enlargement of that Committee. I move, Mr. Chairman, therefore, that it is the sense of this meeting that this Committee should be enlarged to at least fifteen members.

The President.—I presume, Mr. Stern, that your recommendation is to the Board of Direction.

Mr. Stern.—To the Board of Direction.

(Motion duly seconded.)

The President.—A motion has been made and seconded that this meeting recommend to the Board of Direction that the Special Committee on Materials for Road Construction be enlarged to a membership of fifteen. Is that correct?

Mr. Stern.—Yes, sir.

The President.—You have heard the motion, which is before you now for discussion.

F. Lavis, M. Am. Soc. C. E.—I wish to endorse strongly all that Mr. Stern has said. Personally, I was not particularly interested in the construction of roads until the early part of last year, except that I like to have a nice, smooth road to ride over.

Some eight or ten months ago, I became directly interested in the question of the construction of roads, and naturally looked for information where one might best expect to find it, and was surprised at the dearth of really valuable information accessible to a person who had to build a road; and I think it is well within the scope of the activities of this Society to take up the subject actively.

The President.—You have heard the motion. Is there any more discussion? If not, I will put the motion.

Mr. Crosby.—May I say a word? I probably appreciate the importance of road construction as well as any member of the Society; and also appreciate the desire of many members of the Society and others, who for the first time, and within recent years, have had the responsibilities of road construction laid on their shoulders; and I appreciate, also, the dearth of literature on the subject—reliable literature.

The Committee has not, however, from its constitution and the assignment of its responsibilities, felt that one of its duties, or its final duty, was to prepare a textbook on road construction. The Committee was a Special Committee on Bituminous Road Materials, at the start, and a year ago its activities were enlarged to include the non-bituminous materials. Incidentally, of course, it is obliged to deal with methods, to some extent. However, in order not to attempt more than the opportunity offered for the proper performance of the duties, and in order to perform the duties within reasonable limits, as clearly and as fully as possible, the Committee has refrained from attempting to put out information over its signature—over its endorsement—which it was felt was more or less common knowledge, especially among those who were engaged, and had been for some time engaged, in road building.

It has steadily refrained from loading up its reports with generally accepted conclusions, and has attempted to get out the greatest number of new conclusions, or conclusions on disputed points, which the limited time available offered.

Now, if the Committee is to be one to prepare a general textbook on road building, so that any engineer who may have been in architectural or other work, and suddenly becomes loaded with the responsibility of highway and street construction, can with facility turn to that volume and produce results for his employers, I submit that the Committee has a considerable job before it; and it might be wise to enlarge the Committee to make arrangements for its members to give the requisite time from their ordinary duties toward its work, on some such basis as would warrant men capable of performing the duties giving the necessary time to it, and then allow it sufficient time to produce satisfactory results in rather a large field.

On the other hand, if the original conception of the Committee is to be carried out, and a report made of some value on a limited portion of the field, leaving to others the production of literature on other portions, far larger, perhaps, of the whole field, it is a question whether the enlargement of the Committee is desirable.

Discussion on Committee on Materials for Road Construction (continued).

You all recognize, I am sure, the difficulties of attaining as great a percentage of attendance with a large committee as with a small one. The meetings of this Committee—consisting of seven members—have been almost always full meetings. There have been only one or two occasions where any one has been absent. The Committee has had a number of meetings, I should say, perhaps, ten during the past year; and if the Committee were much larger, it is a question whether anything like the record for attendance could be attained, and, consequently, whether the actual results produced would be any more definite, or perhaps any more in volume, than they have been.

Mr. Stern is slightly in error when he refers to seven pages as the report, because the report contains actually twenty-three pages, and the sixteen pages annexed to the report occupied more time of the Committee than the seven pages of the text. As Chairman of the Committee, I do not want to be misunderstood. I do not want to be understood as objecting to the addition of any men to the Committee, if the result wished by the Society would seem to be advanced, but I speak from my own experience as Chairman; and there is some question on that point. I do not wish, either, to take your time now to enter into any argument or extended discussion of the report, because the Board of Direction has kindly set aside Friday of this week for a special meeting of the Society, at which the report can be discussed in detail; and I merely ask you to consider what I may have said on the point.

Mr. Williams.—Mr. Chairman, I would like to call the attention of the membership at this time to certain conditions which have come to the attention of the Board of Direction within the past two or three months. Those conditions are that this matter of Special Committees is running away with the Society. The amount expended on the work of Special Committees during the past year has been found to be a greater burden than the income of the Society warrants at the present time; and it has been decided—or at least recommended by the present Board of Direction to its successor—that a reduction of the allowance for Special Committees be made next year. I believe it is very important that such reductions be made; and I think that we should look particularly to quality rather than to quantity on our committees; and I, therefore, hope that no suggestion of an increase of members of any committee will be recommended by this Meeting.

James Owen, M. Am. Soc. C. E.—Mr. Chairman, I do not suppose that there is a more important subject——

The President.—Will you kindly come forward, Mr. Owen?

Mr. Owen.—I do not suppose that there is a more important question before the people of the United States than this question of roads. I agree with Mr. Stern somewhat in saying that the American Society of Civil Engineers is probably the most prominent body that is capable of handling the matter; and I also agree with him that the American Society of Civil Engineers has done less on the subject of road construction than any other organization in this country. Why that is, I do not know. Of course, as it is at present, road construction is in an inchoate condition. Ideas are prevailing now that did not exist before.

The ideas existing four years ago on road construction are now obsolete, and it seems to me that this Society should take hold of this matter as a business proposition, or rather as a professional proposition, for the benefit of the country.

Now, the Committee has been sitting for four or five years, the restriction that it has imposed on itself in treating on one subject—because I do not know the originally contemplated scope of this Committee—was to take up the leading questions of road construction; but, having restricted itself, as is stated, it seems to me that it is time that that restriction, although self-imposed, should be removed. Of course, I have been interested in the road movement for a good many years, and I know the trouble existing among road engineers in getting satisfactory results; and it seems to me that it is not improper, with all due deference to Mr. Williams, that this Society should take up that subject in the broadest way and most patent form.

I, of course, may feel a little personal in this matter, because in the publications of the Society, I notice that when I made a discussion last year at the meeting of the Society, the Committee on Publications, for some peculiar reason of its own, suppressed it. Now, I think that is not orthodox. I never knew that any Board or officer of this Society was empowered to suppress oral communications that were officially taken by the stenographer and submitted to me for revision. I revised it, and it was returned with a notification that the Publication Committee had decided not to print it.

Now, gentlemen, to my mind, that is something extraordinary, and I still adhere to my idea that this Society should do the best it can, if the members of the present Committee conceive themselves capable of doing it, or the Society conceives them capable of doing it, I say, let this number stand, but my idea is that this Committee should be enlarged to give this country better knowledge of road work.

Mr. Stern.—Mr. Chairman, I regret somewhat that I must speak once more on this subject, which, it is insinuated by the Chairman of the Committee, I know nothing about.

Assuming, for the sake of argument, gentlemen, that I, as a member of the Society of Civil Engineers, know nothing whatever about road building; assuming that I happen to be in a position where it is necessary to know something about road building; is that any reason why a committee appointed several years ago for the purpose

Discussion on Committee on Materials for Road Construction (continued).

of giving us information on this very important subject, should use that as an argument?

What is the object of this Society? I ask you that question. Is it to broaden the knowledge of those who happen to know nothing about some particular specialty, or only to patch up some minute matters which are not accepted as common knowledge, for the specialists?

I reject the proposition that there is anything accepted in road building. My own experience in road building goes back a great many years, probably more years than the Chairman of the Committee seems to think; and I have failed to see anything accepted in road construction throughout the United States or any other country.

Gentlemen, we do not want a textbook. Any statement like that is perfectly absurd. We want recommendations by a Committee appointed by this authoritative body—definite recommendations.

I apologize to the Chairman for saying that there are only seven pages in the report. There are seven pages in the report, plus appendices. Among those appendices are blank forms for getting information regarding traffic, *et cetera*; blank forms for the computation of costs, *et cetera*.

I do not see why a report should be loaded up with that kind of stuff at all.

We want to know how a tar-macadam road should be laid, or a bituminous-macadam concrete should be mixed. We want recommendations from this Committee. We do not want a specification. We want its opinion; that is why it was appointed. That it has not given us.

I believe, however, that, as hundreds of millions of dollars are being spent annually in this country, we should go into this thing, not as an amateur proposition, or on a narrow, limited scale, but on a very large, broad one, and that the functions or limitations of the Committee should not be restricted. If it is necessary to reorganize the Committee in order to do this, it should be done.

I am sorry to have to make this statement. I made a motion, that the Chairman failed to put to the meeting, on the enlargement of the Committee——

The President.—The motion before the meeting is on the enlargement of the Committee.

Mr. Lavis.—I desire to reply to the statement of Mr. Crosby. We do not want a textbook on road building. I think we have as much right to have the principles of road building enunciated by a Committee of this Society, as to have the principles which underlie the operation of our roads.

When I spoke of having the construction of roads thrust on me unexpectedly, it was not as an engineer that I spoke; it was as an officer of the town in which I live and of the county in which I live.

I was asked to decide between the opinions of a number of engineers who were supposed to be expert in road building.

I wrote to the members of the Special Committee of the American Society of Civil Engineers, which was the first body of experts that I could lay my hands on; and Mr. Crosby, among others, was courteous enough to reply to my letters, and give me some information; but, after I had gathered together all the information I could get, both gratuitously from Mr. Crosby and other members of the Society, and paid information from other engineers, I found it was up to me to decide between the opinions of engineers who made the recommendations; and there was no formulation of principles on which roads should be built.

Mr. Crosby.—I am sorry to have to rise again to perhaps a question of personal privilege. Whereas the personal note has been injected, to some extent, in the discussion, I feel that I ought not to sit still and allow it to pass. Mr. Stern stated that I rather scoffed at his knowledge of road building. I did nothing of the kind. I made no personal allusions. My statement was very general, and was not intended to apply to Mr. Stern, unless he chose to apply it to himself. I do not know Mr. Stern's history well enough to know whether it would apply.

I am very glad that the gentleman who just spoke referred to the fact that I was able to give him some information, which I cheerfully did, and to the best of my ability, and I may say that I am only sorry that I was not employed as one of the paid experts.

However, I want to call attention to the fact, which you will all recognize, I am sure, that this Committee has not, of its own accord, limited its work. As a matter of fact, if you will take the trouble to read the reports of previous years and of this year, the question will undoubtedly arise in your own mind as to whether or not the Committee has not actually gone outside the scope of its assignment.

If you will read the title, "Progress Report of the Special Committee on Materials for Road Construction and on Standards for their Test and Use", you will see that the Committee has no right to consider many principles of road building which undoubtedly would be enunciated by a responsible authority. To this Committee was assigned a limited subject. It has endeavored to keep within the limits of its scope, as far as practicable, but has unquestionably gone outside the strict limits in its effort to perform its duties; and I submit that it is not a fair reflection on the Committee to insinuate that it has deliberately restricted its activities.

The Committee admits, as I explained before, that it has not been including in its reports a lot of well-known—at least, among highway engineers of experience—data concerning road materials. Possibly it would be advantageous to include them.

Discussion on Committee on Materials for Road Construction (continued).

The Committee would like to take the time and do the work necessary to do that, but, in view of the other matters seemingly much more important pressing on it, it has felt obliged to omit these hackneyed things.

Now, as regards the forms, I simply want to say that engineers want the orderly accumulation of facts; and that in the attempt to secure them, as just narrated by the previous speaker, great difficulty is had, not only in getting the facts, but in getting them in an orderly and comparable manner; and the Committee feels that one of its accomplishments—if it shall so result—is the provision for an orderly manner of securing facts necessary in highway construction, not only for the solution of present troubles, but of future troubles, in such a manner as is provided by the forms, which they spent considerable time in framing.

Mr. Metcalf.—Mr. Chairman, it seems to me that this question is one of great importance to this Society. It is certainly not a personal one. We are, however, face to face with the fact of the expense of work of this sort to the Society. Now, aside from that matter, which is a vital one, the important question to this Society is: What is the most effective way of carrying on such an investigation and of accomplishing results?

I must confess that, as a result of my experience on committee work, I have come to feel that the most effective work can be done by the smaller committee, and that, in having so large a committee as ten or fifteen men, you not only subject the Society to very heavy and unnecessary burdens of expense, but you actually run the risk of getting less effective results.

It means that the discussions within the Committee may become very burdensome, and to such an extent that members of the Committee may feel even that they cannot give the time to listen to such long discussions of the subject. In other words, it may not be any more productive of good results.

Therefore, I hope—believing, as I do, that the most effective work is done by smaller committees—I hope that the Committee will not be enlarged, as suggested by Mr. Stern; and I would move as a substitute or an amendment to his motion, Mr. Chairman, that the Board of Direction give consideration to the question of the desirability of increasing the membership of the Special Committee on Road Materials, and the scope of the work of the Committee.

The President.—That is, the Board of Direction?

Mr. Metcalf.—The Board of Direction.

The President.—Is there a seconder to that amendment?

(Motion duly seconded.)

The President.—The question is on the amendment submitted by Mr. Metcalf.

Mr. Stern.—As to the desirability of enlarging the Committee, the question arises generally as to how much a committee of seven men can do in connection with this great question.

The Society has a right to ask that we get results within the life of those who are living now. At the present rate of procedure, it does not look much as if we were going to get that. How can we get that? By enlarging the Committee with the right kind of material; by putting men on the Committee who will work, and eliminating those who will not work.

There is no reason why a committee of fifteen should not do twice as much work as a committee of seven, by the appointment of sub-committees. The committee could be sub-divided into two sub-committees, consisting of seven each, and if those sub-committees are selected properly, this committee should, in the course of one-half the time, produce authoritative recommendations and reports.

I hope, therefore, that the Board of Direction will consider this matter, if the motion prevails.

Edgar Marburg, M. Am. Soc. C. E.—Mr. Chairman, I do not think that it ought to go unchallenged that intimation has been made that the appointment of committees is not a good means of doing effective work. It is not necessary to cite examples of many other societies, whose principal work is directly committee work, to refute that statement; and I do not think it ought to go unchallenged.

I think that committee work has advantages which are so palpable that to disregard it would be a reflection on the Society. Committee work implies that some one selects the papers, that the Society or the Board of Direction selects a worth-while subject, and assigns it, presumably, to the most suitable men in the Society to deal with that subject. It also means that the report of such a committee expresses the views of the members composing it. Nor is it necessary to arrive at the gist of the committee's reports, at the essence of the subject, to wade through a paper and discuss it. All that has been done and sifted out by the committee itself.

Nothing can be put forward, in my judgment, more authoritative, therefore, through our publications, than the labors of a properly constituted committee, as indicated by its reports, on a worth-while subject.

Now, the intimation that this Society ought not to give support to encourage committee work because, forsooth, it has not money, is unworthy of consideration. How about the other societies who have almost nothing compared to what this Society has? It is not necessary to mention names. I speak because of the fact that I happen to be connected with an organization that does all its work practically through committees, and the work speaks for itself; but I am not

Discussion on Committee on Materials for Road Construction (continued).

going to mention names. I take it that this body is too well informed to allow that sort of argument to have weight.

And again, if a committee is properly constituted, and applies itself seriously and conscientiously to its task, should not that committee be backed up? Are we here to pass judgment on whether or not a request on the part of the committee to be enlarged to fifteen, should not be granted? We are asked to vote in a matter of that kind against a committee of our appointment, and to say that a committee of fifteen is unwieldy. Do you reckon with the fact that most important work is done by sub-committees? Ought we to sit in judgment on the report of the Special Committee, Mr. Chairman, the members of which are particularly competent to deal with that phase of the subject, whatever phase of the subject happens to be submitted to a Special Committee, without knowing anything of the Committee, but knowing it was appointed by the Board of Direction, and feeling confident that it knows its business?

I would be prepared to vote and lend my voice to any recommendation on the part of the Committee for its enlargement, whether it be 15 or 50——

The President.—May I call your attention to the fact that the enlargement of the Committee is not asked for by the members of the Committee, but by a member outside the Committee, who would like you to enlarge it.

Mr. Marburg.—Has the Committee expressed an opinion on the subject?

The President.—It has opposed it.

George W. Tillson, M. Am. Soc. C. E.—Mr. President, I was not present when this subject was first introduced, when the report was introduced, but I have been here long enough to understand that there is some dissatisfaction with the report of the Committee.

There has been an intimation that the Committee, if it continues at its present rate of procedure, will not be through during the life of many here present; also that the delay in such procedure is not necessary if the Committee works.

I would like to call your attention to the fact that when this Committee was appointed, it was appointed to investigate bituminous materials only, and that a year ago last June the Committee was instructed to continue itself, to begin investigations and make a report on materials other than bituminous, as well as bituminous materials.

It has been stated that this report contains only seven pages as a result of the Committee's work, and appendices regarding forms have been referred to.

If the gentleman who made that remark will read this report, and read Appendix B, and see what that information amounts to, and then form an adequate idea of how much time and investigation is necessary to form such conclusions and put them before such a body as this, as well as taking into consideration all that this report says about materials other than bituminous, I think he will conclude that, within a year and a half, with the amount of time that busy men have to give to such a subject, the Committee has accomplished something.

This Committee, as has been said, consists of seven members. They are busy, active men, employed in actual business, and it is difficult for them to get away. As the Chairman said, at these Committee meetings nearly every member has been present every time; and it not only means giving up the time necessary to attend the meetings, but it also means giving up time outside of the different meetings to investigate things and report to the Committee, and these reports of these different men—call them sub-committees or not—are considered and thrashed out, and the man who makes the recommendation in the Committee has to back it up, just the same as the Committee has to back up its report when it is presented to this body.

I do resent any insinuation that this Committee has not worked, that it has not given its time, and all the time that a committee of busy men can be expected to give to the performance of its duties, much as they would wish to give more.

Now, as to the enlargement of the Committee, I think that most of those who have been engaged in committee work of this kind will agree that it is impossible for a large committee as a whole to get together and discuss these important points.

What is the object of appointing a committee or a body, anyway? It is for some one to take up and consider and work out these things, and report them. If you have no confidence in the Committee, or if you think the Committee is not the proper one, it is easy to get others who can do the work. The personnel of the Committee should be considered when it is made up; but the trouble with a large committee—and that has been proven in this case, with the size that it is now—when the different men come in and make their reports, it often spends half a day or a day discussing some matter which, to the majority of the people, would not be considered of special importance, and if this Committee, or any committee, is to receive the report of a sub-committee without considering it, and without giving its own particular attention to it, what is the benefit of the sub-committee? And the more you have on that sub-committee, the more difficult it is to get results that will be satisfactory to the Committee, and satisfactory to all others, because a committee wants to put in a unanimous report.

If you put in a majority report and a minority report, you leave the subject open. There is nothing settled. The people say the Committee has not settled anything because the members cannot agree among themselves. So I believe that a committee of seven is fully

Discussion on Committee on Materials for Road Construction (continued).

large enough, and personally should be very sorry to see it increased any, not to say to such a number as fifteen.

A. E. PHILLIPS, M. AM. SOC. C. E.—I want to call attention to the fact that the last speakers have not been speaking to the motion before the meeting, which, as I understand it, is an amendment by Mr. Metcalf, suggesting the widening of the scope of the Committee and, in particular, the size of the Committee.

THE PRESIDENT.—He suggested that the matter of enlarging the Committee and the scope of its work be recommended to the Board of Direction.

MR. PHILLIPS.—His amendment was to enlarge the scope of the Committee, particularly the size of the Committee.

THE PRESIDENT.—He suggested that the matter of enlarging the Committee and the scope of its work be recommended to the Board.

MR. PHILLIPS.—His amendment was to enlarge the scope of the Committee, particularly the size of the Committee. I would like to say that I believe that the sense of the Society is to have a committee doing work of this character under a title that apparently is broad—I believe that the sense of the Society is to have its scope enlarged sufficiently to cover the subject with reasonable fullness, unless another Committee is doing the work along broader lines.

I think the motion Mr. Metcalf made is a most excellent one, and I do not think that the members of the Committee or their defenders, who seem to be a little sore that there should be any criticism of their work, ought to feel so, but rather ought to feel that the idea of the Society is not to reflect upon that Committee, but to get wider results than apparently are contained in the report of the Committee, and to cover the subject in a broad way.

I do believe that in a subject developing as rapidly as road building has, a committee of this sort should not confine itself to one class of materials, as it did last year, but should cover all classes of materials, should cover the subject more broadly; but I do not think that any criticism of the Committee should be made by any member or by the Meeting, because its scope has been limited in its assignment, as I understand it——

THE PRESIDENT.—It certainly was.

MR. PHILLIPS.—I hope that the members, in voting on it, will consider whether it is the wish of the Society to broaden the scope of the Committee, and I hope the Committee will consider that if the Society votes for Mr. Metcalf's motion, that it will not be a reflection on the Committee.

THE PRESIDENT.—The motion is on the amendment made by Mr. Metcalf, to the effect that the result of enlarging both the membership and the scope of the Committee be referred to the Board of Direction. Gentlemen, you have heard the motion. Those in favor say "aye"; contrary, "no".

The motion is carried, and it is so ordered.

This amendment takes the place of the original motion.

The next is the Report of the Special Committee on A National Water Law. Is Mr. Newell here?

Report of Committee on A National Water Law.

Mr. Williams.—At the request of Mr. Newell, I beg leave to present this report. I shall not attempt to read the entire contents, but will select such portions as will call to your attention its principal features.*

The President.—It has been suggested, in view of the fact that the hour is getting late, and that all the other Progress Reports have been printed in the December *Proceedings,* that they are before you, and that no report will be called up, unless some member present wishes to have it called up for discussion.

Therefore, the Progress Report of the Special Committee on Steel Columns and Struts;† the Progress Report of the Special Committee on Floods and Flood Prevention;‡ the Report of the Special Committee on Concrete and Reinforced Concrete, are before you.

Reports of Committees on Columns and on Floods.

I beg pardon; I went too far. I call for the Report of the Special Committee on Concrete and Reinforced Concrete; I thought that had been printed; I was wrong. Is Mr. Worcester here?

Report of Committee on Concrete and Reinforced Concrete.

Mr. J. R. Worcester presented a Progress Report of the Special Committee on Concrete and Reinforced Concrete to the effect that the Committee has in preparation its Final Report and expects to present it to the Society prior to July 1st, 1916.

The President.—The report is accepted.

I call for the Report of the Special Committee on Engineering Education, Mr. Desmond FitzGerald, Chairman.

Report of Committee on Engineering Education.

Desmond FitzGerald, Past-President, Am. Soc. C. E.—Mr. President and Gentlemen: I must say that I came here with a great deal of reluctance to-day, to make a Progress Report on Engineering Education; since the action of the Society that has preceded me, I feel, for one, prouder than ever of this Society, and I feel more willing to state that the Committee on Engineering Education, while it has made progress during the past year, is not ready yet to make a final report; and I believe that you will accept my statement in good faith.

Now, the evident shortness of time does not permit us to go into this question more comprehensively, and I think it is better not to do so unless it is desired; but I wish to state that it is my belief that

* See *Proceedings,* Am. Soc. C. E., for December, 1915, pages 2747 to 2751 of Papers and Discussions.

† See *Proceedings,* Am. Soc. C. E., for December, 1915, pages 2753 to 2769 of Papers and Discussions.

‡ See *Proceedings,* Am. Soc. C. E., for December, 1915, pages 2771 to 2787 of Papers and Discussions.

Report of Committee on Engineering Education (continued).

the Carnegie Foundation, which is now making a careful investigation in connection with our Committee, has made, within the last few months, an important advance in the solution of this wide-reaching question.

In view of the limited time, Mr. President, now at hand, I suggest that we postpone this statement for another year.

I have asked Professor C. R. Mann to come here, and he is prepared to tell you something about this advance; but we wish more time to discuss it and to investigate it in the Committee.

The President.—Do you think that Professor Mann would be willing to make a short statement before the members of the Society? Professor Mann, would you care to do so?

Mr. FitzGerald.—It gives me a great deal of pleasure, Mr. President, to present Professor Mann, and he will make a five-minute statement, so that the Society may be thinking over this very point, and, if possible, aid in the solution, for it really means, on all these important questions before the Society, that many minds—not one or half a dozen—that many minds will, in the end, bring this matter to a successful issue.

C. R. Mann, Esq.—Mr. Chairman and Members of the Society: The discussion of the Report of the Committee on Roads and Pavements has been very interesting. If this Committee has been unable after six years of work to submit satisfactory specifications as to how to build so simple a thing as an ordinary highway, is it reasonable to expect the Committee on Education to submit after seven years of work satisfactory specifications as to how to build so intricate a thing as the royal road to learning?

The progress to which Mr. FitzGerald has referred consists in having arrived at a definite formulation of the main problem. Education is an engineering project; and as you all know from experience, the chief difficulty in any project is the precise definition of the problem. Once you have secured an accurate statement of exactly what you propose to do, the doing of it is a relatively easy matter.

Many suggestions have been made to the Committee concerning the needs of engineering schools: as that they be made more vocational and less specialized, that the courses be broadened and simplified, that more English and economics be introduced. The value of these suggestions may be very different for different schools. They therefore do not define the general problem, but rather tend to focus the attention on a line of discussion that leads to no clear and definite statement of the real problem and to no important and far-reaching conclusion.

The real nature of the problem may be discovered by considering the actual condition of the schools from the point of view of organization, of curricula, and of methods of teaching. In the matter of organization the schools differ widely. At one extreme stands the school of the autocratic or military type where the director issues instructions to the professors and the professors direct the instructors, and the instructors command the students. Half way down the series come the schools in which the arts college ideal of academic freedom and departmental autonomy are maintained intact. In these each department is deeply impressed with the importance of its own subject and its own methods of teaching, but finds little occasion for real co-operation with other departments in designing the organization that will be best for the students. At the other extreme stands the school where the faculty co-operates closely and in a thoroughly democratic way in deciding, not only the general type of organization, but the details of the curriculum and the methods of instruction. How can any one decide which of these three types is best adapted to the development of an engineer unless he has a pretty definite notion of what an engineer really is?

The situation is the same when you come to study the various types of curricula. At one extreme we find schools in which the student studies thirteen subjects at one time; at the other are schools in which the student studies only three subjects at one time. Which curriculum is most likely to develop the best engineer, and how can you answer this question unless you have a very definite notion of what the essential characteristics of an engineer really are?

When you go into the details of teaching a given subject, you will find that in some schools chemistry, for instance, is taught in a highly theoretical way, beginning with the general principles and leading to specific applications. In other schools you will find chemistry taught on the basis of problems—practical experiences and practical questions concerning processes actually in use in the world's work. These problems are taken up, analyzed, and the chemical principles involved in them discovered. Which is the best way of teaching chemistry in order to produce the best and most effective engineer?

These are not questions which can be answered *a priori,* although they are frequently so answered in the schools. These questions can only be answered satisfactorily in the way you are answering your engineering problems satisfactorily. First, by determining a satisfactory working hypothesis as to what you are trying to do, and what results you expect to get; and, secondly, by deciding upon methods of measurements and tests by which your results can be measured and tested.

In the schools, we have at present no well-defined standard by which it might be possible to determine which is the best conceivable course; nor have we any adequate means of testing the results of a given course. So that the work of the Committee is now directed toward the determination of these two fundamental necessities. Before we can

Report of Committee on Engineering Education (continued).

analyze the course, and can say this course is probably better than that one, we have to have some kind of a statement as to what it is we are trying to produce. What is an engineer? What qualities are fundamentally important? And, in the second place, we have to have means of measuring our results.

Now, the first of these necessities can only be secured with the help of you gentlemen who are now in the practice of engineering, and who, therefore, understand what the engineer must be. For that reason, the Committee sent last spring a letter to the members of the Engineering Societies, asking, among other questions, What do you consider the fundamental characteristic necessary to success in engineering?

We received in reply to that letter, 1 500 answers from engineers all over the world; we have analyzed those 1 500 answers, and have a tentative definition of what are the characteristics essential for engineering.

This definition tells us that the most important thing for an engineer is "Character", which includes integrity, responsibility, resourcefulness, and initiative. These words were mentioned by more than two-thirds of the letters, and the number of times that they were mentioned give a weight to that item of 41 per cent.

The second in importance is a group of qualities called "Judgment", which includes common sense, scientific attitude, and perspective of life. That has a weight, according to the answers, of 17½ per cent.

The third group on the list is called "Efficiency", which includes thoroughness, accuracy, industry.

The fourth group is called "The understanding of men", including executive ability.

The fifth group is called "Knowledge of the fundamentals of engineering science", and the weight of that is 7 per cent. The last is called the "Technique of practice and of business", and its weight is 6 per cent.

If you combine these six groups into two general groups, then the personal qualities, character, judgment, efficiency, and understanding of men, have a weight of 87%, and the knowledge of fundamentals and of the technique of practice has a weight of 13 per cent.

If this is the correct definition of an engineer, the schools must reorganize very fundamentally. Very little conscious attention is there being paid to those qualities on which 87% of the success of the engineer depends. These personal qualities are usually regarded as a sort of by-product. I do not say that the school does nothing to develop character or resourcefulness, nor that it pays no attention to them. I do say that the development of these important personal qualities is not in the focus of attention of the school. Their attention is focused on the last two items, which have a weight of 13 per cent.

Every one of you, when you employ a young engineer, size him up on the basis of qualities of this sort. You always give first weight to some particular quality, and second weight to some other quality. We are going to ask you to number those groups in their order of importance as you actually use them, when you try to size up young men for your employ, or for promotion, or when you try to judge of the reasons for the success or failure of your colleagues.

If a large number of engineers will do this, so that it becomes evident that the definition is correct, we shall have a working hypothesis or a measuring stick with which to attack the educational problem. It will then be possible to make progress which will be definite, and also to decide such questions as whether teaching chemistry from the theoretical point of view is better than teaching chemistry from the practical point of view.

If you engineers will give the schools a clear definition of what the engineer is, the schoolmen will know how to use it in strengthening the school. We thus ask you engineers simply to tell us what the product should be, and not how the schools should be conducted to secure that product. If you will define the product for the schools, the schoolmen will prove competent to produce it.

THE PRESIDENT.—The members of the Society, I am sure, feel under great obligations for having an opportunity of hearing this interesting statement of the work so far accomplished by the Carnegie Foundation, of which Professor Mann is in charge. I thank you very much, Professor Mann.

Report of Committee on Floods and Flood Prevention.

I have been asked by Col. Townsend, to state that the report which is marked and printed "Progress Report of Special Committee on Floods and Flood Prevention", is the final report. I wish to make that correction.

I now call for the Report of the Special Committee "On Valuation of Public Utilities". Is Mr. Stearns here, or Mr. Metcalf?

Report of Committee on Valuation.

MR. METCALF.—In the absence of Mr. Stearns, I submit the report:

"JANUARY 1, 1916.

"TO THE BOARD OF DIRECTION,
AMERICAN SOCIETY OF CIVIL ENGINEERS,
220 West 57th St., New York City.

"*Gentlemen:* Your Committee on the Valuation of Public Utilities presents herewith its report of progress made during the year 1915.

"The general plan, heretofore adopted, has been continued—that of carrying on, addressed in manifold to all of the members of the Committee, a written discussion upon the drafts of chapters assigned to and prepared by different members of the Committee, and of meeting from time to time for conference and discussion upon the general principles involved in valuation, which should be covered in the report.

Report of Committee on Valuation (continued).

Under this plan a voluminous correspondence has been carried on and the following meetings have been held during the year:

"9. April 8-10, 1915, at New York, three days, full attendance;
10. July 6-9, 1915, at Boston, four days, six members present;
11. October 11-14, 1915, at New York, four days, five members present;
12. December 27, 1915-January 1, 1916, at New York, six days, full attendance upon two days and six members present upon four days.

"To date there have been prepared, subject to possible final revision and modification, chapters upon the following subjects: introduction—discussing the activities and aims of the Committee and the purposes of valuation—glossary, fundamental principles of valuation, property to be included in physical valuation, original-cost-to-date, reproduction cost, depreciation and appreciation, development expense, non-physical values.

"The Committee hopes to be able to conclude in time for publication during the year 1916, perhaps within a six-months period, a report upon the method of applying the more important yard-sticks used in the valuation of public utilities.

"The expenses of the Committee during the past year have amounted to the sum of $419.34, as appears in the report of the Treasurer of the Society. The Committee asks for an appropriation of five hundred dollars ($500), in addition to the balance ($380.66) remaining from the appropriation for the year 1915, for the estimated expenses of the Committee for the year 1916.

"Respectfully submitted for the Committee,

"Leonard Metcalf,
"Secretary."

Discussion on Committee on Floods and Flood Prevention.

Mr. Ockerson.—I move, Mr. President, that the Report of the Special Committee on Floods and Flood Prevention be received, and that the Committee be discharged.

Mr. Williams.—I second the motion.

The President.—You recommend to the Board of Direction that the Committee be discharged.

Morris Knowles, M. Am. Soc. C. E.—The hour is late, and I will not take up much of your time; but it seems to me that, in view of the fact that the membership has noticed that this was a Progress Report, and that in a preliminary report it was stated that the Committee hoped to co-operate with the Special Committee on A National Water Law, and as the latter Committee has indicated in its progress report that there are many steps in which the matter of constructive regulation should be considered, it seems to me to be quite proper that this step should be extensively discussed; but, without going into any further discussion on the matter, I think the Committee should be continued for the purpose of joining with the Special Committee on A National Water Law, as was originally intended, and I so move.

(Motion duly seconded.)

THE PRESIDENT.—Mr. Ockerson, will you withdraw your motion in that case?

MR. OCKERSON.—I withdraw it.

THE PRESIDENT.—I will put the motion that the Committee be continued. Gentlemen, you have heard the motion. Those in favor say "aye"; contrary, "no". Carried.

THE SECRETARY.—I have here a discussion of the work of the Committee on Floods and Flood Prevention, which I ask for leave to print.

THE PRESIDENT.—If there is no objection, it is so ordered.

MR. FITZGERALD.—There is one item of interest that I forgot to mention in the report of Engineering Education: The total expense to the Society for the last three years has been absolutely nothing.

THE PRESIDENT.—A motion that the Committee be continued at the same expense is in order.

I call for the Report of the Special Committee on the Conditions of Employment and Compensation of Civil Engineers. Is Mr. Lewis here? Report of Committee on Status of Engineers.

THE SECRETARY.—I know that that Committee is not ready to report at the present time. Mr. Lewis told me that he expected, within the next month or two, to have a complete report, which would be published in time for discussion at the Annual Convention next June.

THE PRESIDENT.—We will receive that as a progress report. I call for the progress report of the Special Committee appointed to Codify Present Practice on the Bearing Value of Soils for Foundations, *et cetera,* Mr. Robert A. Cummings, Chairman. Report of Committee on Soils.

ROBERT A. CUMMINGS, M. AM. SOC. C. E.—The question of time is involved in what I have to say, and also the fact that I have nearly forty pages here, but as it will be printed later, I will merely submit it.*

THE PRESIDENT.—The progress report is accepted. The Report of the Special Committee on Stresses in Railroad Track. A. N. Talbot, Chairman. Report of Committee on Railroad Track.

Mr. Talbot presented the following Progress Report:

"The Special Committee on Stresses in Track presents the following report of progress:

"It will be recalled that the Committee of the Society and the Committee of the American Railway Engineering Association are co-operating in the work on stresses in railroad track.

"The Joint Committee has held three meetings during the year. At the meeting in Chicago March 16th, 1915, eighteen members being present, the results of the preliminary tests made on track were considered, the conduct of experimental work for the season was discussed, and a general outline of tests was agreed upon as the plan of work for the season. At the meeting held in Champaign-Urbana, June 8th, 1915, seventeen members being present, field tests of the track of the

* This Report will be published in the March, 1916, *Proceedings*.

Report of Committee on Railroad Track (continued).

Illinois Central Railroad north of Champaign were inspected, including static tests and speed tests with locomotive and load dynamometer tests. The programme considered at the last meeting was discussed, and the points upon which it was thought emphasis should be placed were considered and a general programme approved. It was decided to confine the tests of the season to one location. At the meeting in New York, January 18th, 1916, eight members being present, a general discussion of the results of the tests was had.

"The experimental work has made satisfactory progress during the year. A considerable amount of effort has been expended on the development of instruments and methods of conducting the tests. It was apparent in advance that the problem was so complicated, the conditions so variable, and the difficulties so great that satisfactory instruments for determining stresses could be obtained only after long and patient trials. Especially in the case of the instrument for measuring strains in the rail under moving loads were difficulties found, and it was only late in the season, after repeated trials and changes, that the instruments for measuring strains in the rail under rapidly moving loads were put into acceptable form. It was believed to be important that these instruments should make a continuous record of the action of the rail under and between the wheel loads of the moving load. It was found essential that the stresses on both sides of the rail be measured simultaneously. A method of finding the depression of the track under moving load by photographic methods has been developed. The measurement of stresses under static loads was not found to be difficult, although the time consumed in this test is considerable.

"The field tests have been conducted on the main line of the Illinois Central Railroad north of Champaign. Only the general character of these tests can be outlined in this progress report. Data were taken to determine: (1) the distribution of stresses and moments along the rails for a given loading; (2) the division of vertical load among adjacent ties for a given loading; (3) the distribution of vertical pressures among the ties, through the ballast, and over the roadbed; (4) the depression, compressibility, or stiffness of the track; (5) the effect of wheel spacing of some types of locomotives, and also the effect of single and double concentrated loads; (6) the effect of speed upon most of the foregoing items. Tests have been conducted at speeds as high as 65 miles per hour. Among the variables of the track were three weights of rail, two sizes of ties, and three depths of ballast. In addition to tests on standard track, minor tests have been made at spots where uneven tie spacing, or worn or decayed ties, may affect the stresses developed. The Illinois Central Railroad Company has provided the locomotive and crew. The calculation and compilation of the results has proved to require a great deal of time. The data are now being put into shape, and it is expected the results will be ready soon for the consideration of the Committee. The results appear to give fairly definite quantitative values for stresses in the rails and for the general distribution of loads and pressure under the various conditions of the test. The Committee believes that it will be able to determine the general action of the track under moving loads. It is the purpose of the Committee to report to the Society at an early day the results of the tests already carried out.

"The Committee plans to continue the tests during the coming season, to complete the matters already partly covered, and to extend the experiments to include other features like action on curves and on track of different kinds.

"Respectfully submitted.

"A. N. TALBOT,

"*Chairman.*"

THE PRESIDENT.—Is there any new business to come before the meeting?

R. S. BUCK, M. AM. SOC. C. E.—Mr. President, I beg leave to offer for the consideration and action of this Meeting, certain resolutions for which it seems to me, the opportunity seems most fit.

Resolution on Mobilization, etc., of the Resources of the Country.

Strenuous efforts are being made just now, chiefly at Washington, to inaugurate progress in naval development commensurate with the compelling needs of National safety, and this Society, as well as the other societies, has been participating very effectively in a professional and technical way.

This matter seems to rest largely on what the sovereign silent people want, or at least, want to an extent that will help, and on this crucial point there seems to be much doubt.

Libraries have been written on this subject in the press, in the magazines, and in every form of volume, covering every range of fact, alleged fact, thought, or imagination.

"*Whereas:* We believe that the United States has definitely adopted the following policies:

"To sustain the Monroe Doctrine;

"To retain, subject solely to its own will, guardianship, or control over all territories it now holds;

"To protect the rights of its citizens to freedom of travel and traffic on the high seas; and

"To protect the rights of all people within its borders in the pursuit of legitimate business; and

"*Whereas:* We believe that these policies are logical, just, wise, and beneficent, not only to the people of the United States, but to all peoples of the World, and are without purpose of territorial expansion or unfair quest of commercial advantage; and

"*Whereas:* The far-reaching, unprecedented, and terrible events of the last two years have indefinitely deferred the hope of establishing and maintaining the rights of nations and peoples by means of peaceful justice alone, and have forced the conviction that, as yet, no nation can safely maintain its rights, however firmly rooted in justice, without the aid of effectively developed physical force; and

"*Whereas:* The United States, by reason of sincere but erring faith in the advent of universal domination of peaceful policies has not maintained its Army and Navy establishments on a basis to meet the severe test of a great war, which has so long appeared a remote and receding possibility, but which is now an imminent and overwhelming reality; and

Resolution on Mobilization, etc. (continued).

"*Whereas:* Every dictate of dignity, reason, patriotism, and self-preservation demands that these establishments be placed as promptly and firmly as possible on a basis of strength and efficiency which will enable them to cope adequately with the enormous, exacting, and relentless task which, in support of our national policies, they may at any moment have to perform; and

"*Whereas:* Civil Engineering has, through its great range of experience in handling men and materials in all parts of the world and under all possible conditions, furnished the fullest demonstration of the fact that knowledge and skill derived from continuous effort and years of arduous training are essential to the successful performance of all great tasks, be they Civil or Military;

"*Therefore, be it Resolved:* That it is the sense of this Annual Meeting of the American Society of Civil Engineers that our national policies, both at home and abroad, imperatively demand, not only extensive, well-planned, and effectively and promptly executed enlargements of our Army and Navy establishments, but also a thorough and efficient plan of mobilization of those ponderous industrial and transportation resources of the country which are essential to the creation and operation of these establishments; and be it further

"*Resolved:* That it is the sense of this meeting that the adequacy of the Army and Navy establishments for properly supporting our national policies, as adopted by superior Civil Authority, should be determined by the Army and Navy experts who have devoted their careers to dealing with the vast and intricate problems involved, and who, both by reason of their technical knowledge and experience, and by further reason of their integrity, loyalty, patriotism, and ability, should commend the fullest measure of confidence at the hands of the Government and of the Public; and be it further

"*Resolved:* That it is the sense of this meeting that, although complete subordination of all branches of the Army and Navy to superior Civil Authority must at all times be maintained, such Civil Authority owes to itself, to the Army and Navy, and above all to the people whom it in turn serves, effective recognition of the superior claims of the findings of trained and tried experts as against party politics, sectionalism, insincere appeals for economy, transient expediency, private interests, and in fact against all other considerations than those of broad, sound, and just national policy; and be it further

"*Resolved:* That a copy of these resolutions be sent to the National Security Congress to convene to-morrow at Washington, through the Chairman of the Committee on Engineer Reserve, and that copies be mailed to the President of the United States, to the members of his Cabinet, and to the members of both Houses of Congress."

Discussion on Resolution on Mobilization, etc.

Mr. FitzGerald.—Mr. President, Fellow-Members of the Society: While there is a great deal both in these preambles, which have been read to us, and in the resolutions themselves, which undoubtedly awaken in our hearts a sympathetic response, I believe that they have been put in a very imperfect form.

I do not think that the majority of the members of this Society are willing to concede for a moment that the American people, as a people, have been so low in their aims and desires as to put money before character. I do not think we wish this to go abroad as our view of American life. Then the resolutions are singularly lacking in simplicity. It is almost impossible to know for what we are really to vote; and I move, therefore, Mr. President, without further remarks, that they be referred to the Board of Direction.

(Motion duly seconded.)

F. W. Skinner, M. Am. Soc. C. E.—Mr. President, I do not question the resolutions, which I think are somewhat long and involved, and I am not quite sure as to their meaning, but I would like to say one or two words regarding the importance of preparedness for this country. I have just returned from a five months' trip abroad. Much of that time I spent in the war zone. Some of the teachings of this war, as they affect the United States, have touched me most forcibly. The first is, that in this great conflict, which has already cost perhaps five or six million lives, the engineering operations and engineering progress have been the great factor. Hundreds of thousands of troops have been massed and thrown forward to their destruction, and have been destroyed by the superior engineering resistance that was offered, beginning, if you like, with the wonderful railroad system, which has enabled the Kaiser's hordes to be moved from side to side with such rapidity that they seemed almost to be simultaneously in opposite places, and then following with the developments of the submarines and aerial warfare.

It seems that nothing rests on its former plane, and that almost all the great elements of change in warfare are due to the wonderful engineering plans and advances which have been made with aeroplanes, going 11 000 ft. per min.; with other aeroplanes that have armored cabins, carrying eight men, four large guns, and two small ones, and other plans in proportion; with Zeppelins which weigh 20 tons, and have proved to be engines of tremendous dynamic force; with submarines that have effected results which we have seen and which in their turn are controlled by plans prepared by engineers against them; with submerged mines that have to-day reached such a state of perfection that in water of unknown depth they can be casually thrown overboard and permanently anchored in position an exact number of feet below the surface; with range-finders, which, without exposing the observers, give the exact range for miles; with artillery so arranged that it can be massed on one point and then have a range of 15 or 20 or even 24 miles; it shows the importance of the engineer, and the right which this body has to take aggressive steps towards preparedness.

The necessity for preparedness I think is easily manifested by the great facility with which any of the armed nations now in conflict could reach the United States. We have earned, to say the very least, dissatisfaction in foreign countries. Our policy has been neither

Discussion on Resolution on Mobilization, etc. (continued).

for nor against, and it has been very distasteful to some of our neighbors and some of our friends. Possibly, then, at the end of this conflict——

The President.—May I call the attention of the speaker to the fact that time is pressing; that I feel most of us are in entire sympathy with the spirit of the resolutions submitted, and if he will cut his remarks short, I think he will get the attention of the members now present.

Mr. Skinner.—It seems to me that this body of engineers, more than any other body of engineers in this country, is entitled to take active measures to assist our country in preparedness, and that one of the great measures and dangers to which we might become easily exposed, and which it lies with engineers to foresee and combat—it is my personal experience after five months of war—on one occasion there came within a block of my lodging, a Zeppelin which passed over twenty miles of the congested districts of London and which, I believe, must have caused at least one thousand deaths——

A Member.—May I ask what is the motion before the meeting?

The President.—The motion before the meeting is that the resolutions which were presented be submitted to the Board of Direction for editing, if the Members of the Society see fit to adopt them.

R. W. Hunt, M. Am. Soc. C. E.—Mr. President, I must oppose that motion as it is stated. It happens that this Congress convenes to-morrow, and will be in session three days. It is my fortune to be a delegate to it from Chicago, from our home organization. Mr. Parsons, as I understand it, comes from New York, and I think that our hands, if Mr. Parsons will permit me, will be strengthened by a vote and a recommendation and the statement of this great organization.

We are for our country, or we are against it, and now is the time to speak. With all deference to the Board, unless it acts to-day, the force of that action, let it be ever so emphatic, will be lost. I would, therefore, move an amendment to that, sir, that these resolutions, as presented by Mr. Buck, be submitted to the Board of Direction with instructions that it will edit them to its best judgment and give them to Mr. Parsons to-night, so that he can use them to-morrow.

Mr. Williams.—I question the language of the resolutions which are offered, though I am in sympathy with their purport. I do not believe that it is competent for this meeting to instruct the Board of Direction. I think that it can request the Board of Direction, and I think the Board of Direction will be likely to accede to its request, according to its best judgment. I therefore suggest that the word "instruct" be changed to "request".

Mr. R. W. Hunt.—I have been obeying orders all my life, and I may have made a mistake in the language.

The President.—Gentlemen, you have heard the motion which is submitted as an amendment, as I understand, to the original motion.

Mr. FitzGerald.—Yes; I would like to have my original motion clearly understood. It was that this matter be referred to the Board of Direction to take such action as seems desirable.

Now, if it is desired by this meeting that this action should be taken at once, why it is easy enough to add that to the request as the sense of this meeting that the Board of Direction should take such action. It has, however, been my experience through life that where we proceed too rapidly in a matter of this kind, we are very apt to make mistakes.

Certainly, this is an important and a vital step, and we who love our country and wish to see it properly protected, do not want to make mistakes. We want to have preparedness properly considered, and I think that is really at the bottom of this gentleman's own motion —at the bottom of his own idea. He has made his preamble for the resolutions to stand on, like the foundation of a monument, without considering the nature of the resolutions, and I think the resolutions themselves are cumbersome and lack simplicity, as I said before, and, therefore, are not practicable enough. No one wants to read such long resolutions, to begin with.

Now, my idea was to refer this to the Board of Direction, just as we refer everything else, not demanding that the Board take action to-day or to-morrow, but if it is the sense of this meeting by a subsequent motion that it is desirable that that action should be taken to-day, why, pass a resolution and tell the Board of Direction so. Then that leaves it unfettered; it has the matter in hand, at any rate.

But, if it is the desire of this meeting to-day that this question, that these resolutions be properly edited, and that they demand attention, then the Board of Direction knows that that is the sense of the meeting.

Mr. Williams.—You will excuse me for speaking again. It occurs to me that possibly the movers of both resolutions might be willing to accept a substitute, namely, that this meeting declares its approval of the general sense and purport of the resolutions submitted, and requests that the Board of Direction consider to-day the preparation of suitable resolutions to be transmitted to the meeting of the American Security Congress through its Committee on Military Preparedness.

Clemens Herschel, Vice-President, Am. Soc. C. E.—Mr. President, I do not believe in putting down democracy in the government of this Society. I do not know why this large meeting of members of the Society cannot instruct the Board of Direction. I am a member of the Board of Direction, and I welcome instruction of that sort from a body like this.

Discussion on Resolution on Mobilization, etc. (continued).

THE PRESIDENT.—Are you willing to accept the suggestion made?

MR. R. W. HUNT.—Yes, sir, I am.

THE PRESIDENT.—Will you accept that amendment that has been made by Mr. Williams?

MR. FITZGERALD.—No, sir; I think my original motion was a clear and simple one, that the matter be referred to the Board of Direction. Now, then, if we want it taken to-day, let us pass a vote that it is the sense of this meeting to-day that that action should be taken to-day.

THE PRESIDENT.—I would suggest that the motion be divided into two parts, that we first take a vote on the matter of referring it to the Board of Direction, and then we take a vote on the question of an immediate report on it by the Board of Direction.

MR. WILLIAMS.—I will offer my resolution as an amendment—as a substitute amendment—to Mr. FitzGerald's motion.

(Motion duly seconded.)

THE PRESIDENT.—That being the case, the motion is on the substitute amendment to Mr. FitzGerald's amendment. Will Mr. Williams state it clearly?

MR. WILLIAMS.—The substitute is that this meeting declare its sympathy and general approval of the principles set forth in the resolution as offered by Mr. Buck, and that the Board of Direction be requested to consider to-day and prepare a suitable expression of those ideas, to be transmitted to the American Security Congress to-morrow, through the Committee of this Society on National Preparedness.

MR. HERSCHEL.—I move to amend by changing the word "request" to "instruct".

THE PRESIDENT.—Do you accept that, Mr. Williams?

MR. WILLIAMS.—I accept that.

THE PRESIDENT.—Mr. Williams is no longer a member of the Board of Direction, so he is willing to have his former colleagues directed. The motion is then on the substitute offered by Mr. Williams. Those in favor of the substitute signify by saying "aye"; opposed, by the same signal.

The motion is carried.

MR. FITZGERALD.—May I suggest that that is a little awkward: Those in favor of the motion to signify by saying "aye"; those opposed, by the similar signal. I think it is not quite understood.

THE PRESIDENT.—I will put the motion again, to satisfy Mr. FitzGerald. Those in favor of the substitute as moved by Mr. Williams will please say "aye"; those opposed to the motion signify by saying "no".

The motion is carried; the substitute amendment takes the place of the original motion.

I will now put the original motion as amended. Those in favor of the original motion as amended will signify by saying "aye"; those opposed by saying "no".

The substitute amendment to the original motion is carried.

Is there any other new business? If not, the Secretary, I think, has some announcements.

Announcements.

THE SECRETARY.—There are very few. In order to get the matter on record, I have to report and will read the names, if the meeting desires, of those who have been elected by the Board of Direction since the last meeting of the Society: 6 Members, 67 Associate Members, and 21 Juniors have been elected, 21 Associate Members have been transferred to the grade of Member, and 20 Juniors have been transferred to the grade of Associate Member.* The names are here.

Elections.

THE PRESIDENT.—They will be printed. There is no reason for taking up the time of the members by reading them.

THE SECRETARY.—I have to announce the following deaths:

Deaths.

WILLIAM W. FOLLETT, of El Paso, Tex., elected Member, July 5th, 1893; died December 30th, 1915.

CHARLES CONRAD SCHNEIDER, of Philadelphia, Pa., elected Member, February 6th, 1884; Director, 1887; 1898-1900; Vice-President, 1902-1903; President, 1905; died January 8th, 1916.

JAMES KNAPP WILKES, of New Rochelle, N. Y., elected Associate Member, June 3d, 1891; Member, April 3d, 1906; died January 9th, 1916.

DAVID WILLIAMS, of St. Johnsbury, Vt., elected Member, May 4th, 1898; died November 27th, 1915.

LOREN EDWARD HUNT, of San Francisco, Cal., elected Associate Member, June 3d, 1903; died January 9th, 1916.

LUDLOW VICTOR CLARK, of Philadelphia, Pa., elected Associate, October 4th, 1892; died December 28th, 1915.

Annual Convention of 1916.

THE SECRETARY.—I have also to announce that the Board of Direction has decided that the next Annual Convention of the Society is to be held in Pittsburgh, Pa., during the last week in June. The dates are from 27th to 30th, inclusive; and that a local committee of arrangements has been already appointed, consisting of Messrs. George S. Davison, J. A. Atwood, R. A. Cummings, Richard Khuen, Morris Knowles, D. W. McNaugher, Emil Swensson, E. B. Taylor, W. G. Wilkins, and Paul Wolfel.

Programme.

THE SECRETARY.—I do not think, Mr. President, there is any special necessity of saying anything about the programme of the Annual Meeting; every one has it, and the details are there. It has been suggested by a gentleman who knows about the temperatures up at the Kensico Dam site, that those who go on the excursion to-morrow wear arctics or warm rubbers.

* The names of those elected and transferred are printed on pages 70 to 73 of this number of *Proceedings*.

THE PRESIDENT.—The next thing in order——

MR. FITZGERALD.—I should like to give notice that Boston is going to make an effort to have the Convention during the following year. I want you all to bear that in mind.

FRANCIS LEE STUART, M. AM. SOC. C. E.—Mr. President, as a Member and ex-Director of the Society, who is not on any committee, I know I voice to you a very large proportion of the Society's approval, and their intense interest in your committee work, and, referring to the report by Mr. Williams, I hope—and I know I voice the sentiment of the members of the Society—that the Board of Direction will use every financial resource they have to keep the work going on.

Ballot for Officers.

THE PRESIDENT.—The next thing in order is the report of the Tellers.

The Secretary read the Report of the Tellers, as follows:

"220 West 57th St.
New York, N. Y.
JANUARY 19TH, 1916.

"TO THE SIXTY-THIRD ANNUAL MEETING
"AMERICAN SOCIETY OF CIVIL ENGINEERS:

"The Tellers appointed to canvass the ballots for Officers of the Society for 1916 report as follows:

"Total number of ballots received		1 894
Ballots without signatures	36	
" stamped, not signed	5	
" from members in arrears of dues	12	
Total number not entitled to vote		53
Ballots canvassed		1 841
Defective	2	

"For President:

E. L. CORTHELL	1 822
Scattering	11

"For Vice-Presidents:

ALFRED CRAVEN	1 806
PALMER C. RICKETTS	1 809
Scattering	18

"For Treasurer:

LINCOLN BUSH	1 832
Scattering	2

"For Directors:

"District No. 1.	VIRGIL G. BOGUE	1 780
	ALEXANDER C. HUMPHREYS	1 779
	Scattering	17
"District No. 2.	OTIS F. CLAPP	1 772
	Scattering	8
"District No. 4.	RICHARD KHUEN	1 774
	Scattering	5

"District No. 5.	F. G. Jonah	1 772
	Scattering	15
"District No. 7.	Edwin Duryea, Jr.	1 763
	Scattering	16

"Jas. F. Sanborn,
"Lewis E. Ashbaugh,
"David R. Cooper,
"J. H. Granbery,
"J. Daniels Richardson,
"Tellers."

The Secretary.—Before an announcement is made, I suggest that a vote of thanks be given to the Tellers for their work. They came here last night and worked for several hours, and I think it was a very nice thing for them to do.

T. Kennard Thomson, M. Am. Soc. C. E.—I so move.

(Motion duly seconded and carried.)

Officers Elected.

The President.—In accordance with the report submitted, I hereby declare Mr. E. L. Corthell elected President for the ensuing year, and as Vice-Presidents, Messrs. Alfred Craven and Palmer C. Ricketts; as Treasurer, Mr. Lincoln Bush; as Directors, Messrs. Virgil G. Bogue, Alexander C. Humphreys, Richard Khuen, O. F. Clapp, Edwin Duryea, Jr., and F. G. Jonah.

The time has now come when I must step out of office. Fortunately, I have held it for so short a time that it is not difficult to let go. A year ago, when I appeared before you, I said that I would try to devote my entire strength to the best interests of this Society, and in furthering the interests of the Society. I counted on, and had to rely very largely on, the hearty co-operation of the members of the Board of Direction.

I can certify to you that the work of the Society has been carried on steadily during the past year, and that I have been heartily supported, in everything I have tried to do, by the members of the Board.

I tender to them—to those who remain and to those who are going out—my sincere thanks for the manner in which they have tried to aid me in what I wanted to do.

To you, in turn, I tender my sincere thanks for the honor you conferred upon me. As I said before, I hate to step down, but when a man steps down for a better man, nothing better can be done.

I have the very great pleasure in introducing to you as your new President, Mr. Elmer L. Corthell, who really needs no introduction to you. I know of no man to whom the interests of the Engineering Profession have been more at heart. He has labored in season and out of season for the recognition of the engineer in all walks of life.

Such recognition has come to him, and I would ask Past-President Hunter McDonald, to bring our new President to the chair.

(Mr. McDonald conducted Mr. Corthell to the chair.)

Remarks by President Corthell.

Elmer L. Corthell, President, Am. Soc. C. E.—It is rather late in life, but I am ready for it. After 21 years passed in foreign countries, South America and Europe, I am back again in my own country—after spending 16 of the 21 years elsewhere, largely engaged, almost altogether, in engineering professional work connected with International Societies, navigation and road congresses, *et cetera,* in Brazil, Argentine, Mexico, and elsewhere; and while I know very few men here, comparatively speaking, on account of long absences during perhaps a quarter of a century, I am willing to undertake to do the best I can during the next year. I know what I have to do. I know some of the things that are to be done. I have been told that I have a job on hand, several of them. I can name those now in which I am personally interested, and in which I approve what I know to be the sentiments of this Society, one of which is to decide upon the Nationalism of all the engineers of the United States. That is going on. It has practically been done. I understand it was done yesterday. So that now it rests upon you, and upon me, when the vote comes, to attend to our duty.

In the next case, we have grown to be eight thousand, I am told, rather a large body to be handled by an archaic constitution; and that is another matter coming up, in which we will need the good judgment, the attention, and interest of all the membership of this Society.

There is another matter, to my mind an important one. I refer to the relations between the National Societies (some as large as we are, and doing just the kind of work that we are doing, important engineering work for the benefit of the public at large), and the local societies that are also doing their work. Look at Philadelphia. In a wild campaign which they had a few days ago, they doubled up their membership; and Chicago, Boston, New Orleans, and St. Louis are doing their work by themselves. Many of their members are members of this Society, but they have their interests in their own localities.

The tendency all the time is to work together, and this we ought to encourage; and during the next year work out that problem.

Now, these are engineering professional domestic problems.

There are other great problems; and one great domestic problem has been brought forward to-day. It is not my intention to go into the subject. You have given a task to the Board of Direction for this afternon, which is quite important. I want to state that, about a year ago, I myself brought forward a resolution on a National Reserve Corps of Civilian Engineers, and was immediately sat upon, but the subject was referred to a Committee of the American Institute of Consulting Engineers; and in a few days I became its President; my motion had been for the President of the Institute to appoint a Committee on the subject; and I appointed a good strong Committee, and that Committee took up the matter, and, later, came along the Committees of the other societies.

I had personally been elected a Chairman of a certain meeting, and I felt that I had some duties upon me personally, and for many months I conducted with the Secretary of War, and with the War College, all the matters relating to the subject of a National reserve corps of civilian engineers. Then there was a Committee appointed, a Joint Committee of all the societies; and then, on my suggestion, the Chairmen of those five Committees were selected and authorized by their various societies to act as an Executive Committee, to carry the matter forward; and when that was done, I wrote to the Secretary of War that he should thereafter communicate with the Chairman of those Chairmen, and that was Mr. Parsons, who has since been hard at work moving the matter forward.

I was in Washington last month on a very important Congress, the Second Pan-American Scientific Congress, and I know what Mr. Parsons has been doing.

Now, this matter is something that the new Board of Direction must take up this afternoon, and must bring it to a point where we can present a proper resolution to the National Security Congress being held to-morrow and the next day in Washington.

There is another subject, and I am going to make a report now. It will take me about five minutes, a report about a Congress in which I represented this Society on the Committee; and further than that, was appointed by the Secretary of State as the Secretary of Section 5, Engineering, of the Second Pan-American Scientific Congress, on which, by the way, I had been working for months, and I went to Washingtor ten days before the Congress met, in order to help General Bixby, the Chairman of Section 5, to prepare for it.

Now, I am not going into the details here, but I want to say to the members of this Society that that Congress has placed upon you a duty. That duty is to do cordially and fully what our Latin-American engineers of twenty-one republics want us to do, and that is to assist them in various ways looking to the general usefulness of the Engineering Profession in the whole Western Hemisphere.

At the last meeting—the final meeting of that Congress—there were passed certain resolutions, of which Section 5 had seven or eight, looking to the very work you are doing, only of an International scope; for instance, the laws of water, covering that whole subject, to be investigated by an International Committee.

Another was the uniform gauge for railways in the Western Hemisphere. Another was a standardization of specifications and tests of materials. Another was for a uniform or a proper nomenclature of engineering and scientific terms now different in Latin America and

Remarks by President Corthell (continued).

the United States; and I might mention several more, all of which are important.

Now, the result is this, that the countries are going to work to select the members of International Committees, which are going to handle these great engineering questions for the Western Hemisphere; and this Society will be called upon to do much work in connection with it, and it will be of immense advantage, not only to the United States, but to other countries.

This question of education, which we are studying now, is a very important one, and is of very great importance to Latin America. They are sending their students here, and professors of the various universities and technical schools will bear me out in the statement that numbers are coming, many more than are here now. They spoke to me about it. They say: "We are sending our young men to your technical schools to be educated". How important it is that the Committee of this Society should soon decide upon the proper method of providing technical education to these young men coming to all these schools.

Now, I will not dwell on this subject any longer. It is a sort of quasi report that I am making to the Society.

There is another thing that you will be interested to know, and that is that quite a number of the leading engineers, not only those who were at the Congress from Argentine, from Colombia, and other countries, but many more in those countries who were unable to come, desire to join the American Society of Civil Engineers, and have asked me to send the necessary documents to their homes, so that they can present their applications to this Society. Some of them I know personally are men of very high standing as engineers.

So this Congress has accomplished a great deal in the way of developing engineering in all the twenty-one republics of the Western Hemisphere.

Now, there is one great subject I just want to allude to, and that is the internationalism, not only of Pan-America, but also of the world. It just makes our hearts bleed to know that, although three years ago, or less time than that, we thought that our great international organizations, like the Navigation Congress and the Road Congress, and the Railway Congress, were all moving forward to accomplish great things for humanity. Now, look at us. It is enough to make one weep to see the hostility, the acrimonious feeling and everything that is hard, that has broken us up; and here we are, isolated in our own country, doing our own work all right, and satisfactorily, but abroad they are hating each other.

It is only three years ago, when at Quebec, the International Navigation Congress was about to disband, when I myself was called upon to make some remarks, and I brought forward the idea that the meeting of engineers in that great International Congress and Association, was doing more for the peace of the world, than all else that could be done, and yet there is no peace.

Now, the time is coming along when this war is going to be over. It will not last forever; and it will be for us, on this side of the water, who have tried to keep ourselves in peace and in neutrality with all the nations, to help heal the wounds and bring them together.

Now, I want to relate one incident, and President Marx will probably remember it, to show that while this hatred exists between the Nations, I do believe, when you get right down to the bottom of things, the engineers are still friends. I will tell you why.

In 1898, at the Navigation Congress held in Brussels, there was an excursion to Antwerp; and we were taken on board a steamer to examine the navigation and report conditions at that city. We were at war with Spain, and there was to be a very prominent Spanish engineer on that trip; and the question was—I had heard it spoken of—how were these two men—Churruca and Corthell—to meet, with their countries at war? Without making any demonstration, when we saw each other, we fell into each other's arms, and patted each other on the back in true Spanish style, and all about us said "That shows the fraternity that exists among engineers for each other, no matter from what country they come, and no matter whether those countries are at war or not".

Now, when this war is over, there is a task for us, to try to bring together men in these great international organizations of engineers, the engineers of the whole world, no matter what the situation has been.

Now, these are some of the things that I have in my mind for the coming year. I am not going to ask you to help me to carry them out—either domestic or foreign—I know you will help me, and I shall rely upon the rank and file, if I may call it so, of this great Society, as well as upon my associates in the Board of Direction.

The Secretary.—The President asks me to announce that the meeting of the Board of Direction will be held in the room off the reading room on this floor, directly after the adjournment of this meeting. Lunch will be served to the Directors there, so that they need not try to get something to eat before they go there. We have to get this resolution in shape.

The President.—I declare the meeting adjourned. Adjourned.

EXCURSIONS AND ENTERTAINMENTS AT THE SIXTY-THIRD ANNUAL MEETING

Wednesday, January 19th, 1916.—After the Business Meeting lunch for about 650 members was served at the Society House.

At 2.30 P. M., through the courtesy of the Public Service Commission for the First District, Alfred Craven, M. Am. Soc. C. E., Chief Engineer, and the Rapid Transit Subway Construction Company, Contractors, about 225 members made an inspection of a portion of the Lexington Avenue Subway from 38th to 53d Streets.

At the same time, through the courtesy of the Department of Docks and Ferries, R. A. C. Smith, Commissioner, and Charles W. Staniford, M. Am. Soc. C. E., Chief Engineer, and also the Holbrook, Cabot, and Rollins Corporation, Contractors, a party of about 150 members visited and inspected the new 1 000-ft. pier now being built at 46th Street and the North River.

At 9 P. M. there was a Reception, with dancing, at the Hotel Astor, at which the attendance was 571.

Thursday, January 20th, 1916.—The day was devoted to an excursion to the Kensico Dam, by invitation of the Contractors, H. S. Kerbaugh, Inc. The party, consisting of about 470, was conveyed to Valhalla, near the site of the dam, in a special train which left the Grand Central Station at 10.20 A. M.

It will be recalled that on January 16th, 1913,* the Society visited the Kensico Dam, which was then under construction, only 80% of the excavation having been completed, and representing only 22% of the main contract. On the present occasion, the members found the dam in use and practically completed. The contract, for the dam and some of the appurtenant works, was let in 1910, and required all work to be finished by February 14th, 1920. The progress has been so rapid, however, that the entire contract is expected to be completed in 1916, about 4 years ahead of the requirements.

After inspecting the dam, the party was entertained at luncheon as the guests of the Contractors.

The party left Valhalla at 3.25 P. M., and arrived at the Grand Central Station at 4.35 P. M.

In the evening, at the Society House, there was a lecture by Nathan C. Johnson, M. Am. Soc. M. E., with motion pictures, showing the manufacture and nature of concrete. This was followed by a social and informal smoker, at which the attendance was about 1 020.

The following list contains the names of 790 members of various grades who registered as being in attendance at the Annual Meeting. The list is incomplete, as some members failed to register, and it does

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* *Proceedings*, Am. Soc. C. E., for February, 1913, p. 104.

not contain the names of any of the guests of the Society or of individual members. It is estimated that the total attendance was about 1 200.

Abbott, C. P. . White Plains, N. Y.
Abbott, Hunley. . . New York City
Ackerman, J. W. . . Auburn, N. Y.
Addis, W. G. . . . . Winthrop, Mass.
Aikenhead, J. R. . . Boonton, N. J.
Aims, W. I. . . . . . . New York City
Alderson, A. B., West Hartford, Conn.
Alexander, H. J. . New York City
Allen, C. M. . . . . Worcester, Mass.
Allen, F. W. . . . Mt. Vernon, N. Y.
Allen, Kenneth. . . . New York City
Ammann, O. H., New Brighton, N. Y.
Andrews, Horace. . Albany, N. Y.
Appleton, T. A. . . . Beverly, Mass.
Armstrong, R. W. . New York City
Ashbaugh, L. E. . New York City
Ashmead, P. H. . . . New York City
Atkinson, Asher, New Brunswick, N. J.
Atwood, T. C. . New Haven, Conn.
Austin, W. E. . . . . New York City

Babcock, W. S. . . . New York City
Baker, P. S. . . . . Philadelphia, Pa.
Baldwin, A. S. . . . . . . Chicago, Ill.
Baldwin, W. J. . . . Brooklyn, N. Y.
Bamford, W. B. . . . Belmar, N. J.
Banks, C. W. . . . Mt. Kisco, N. Y.
Barnard, E. E. . . . Lynchburg, Va.
Barnes, T. H. . . . . New York City
Barney, P. C. . . . . . New York City
Barney, W. J. . . . . New York City
Baum, George. . . . Yonkers, N. Y.
Beaty, R. E. . . . . . New York City
Beebe, H. R. . . . . Utica, N. Y.
Beekman, J. V., Jr. . Boston, Mass.
Beggs, G. E. . . . . . Princeton, N. J.
Belcher, W. E. . . . New York City
Belden, E. T. . . . . Pittsfield, Mass.
Belknap, J. M. . Manhasset, N. Y.
Belknap, R. E. . . . New York City
Bellows, S. R. . . . . New York City
Benson, Orville. Pequannock, N. J.
Bentley, J. C. . Hackensack, N. J.
Berger, John. . . . . . New York City
Bettes, C. R. Far Rockaway, N. Y.
Betts, R. T. . . . . . . New York City
Beugler, E. J. . . . . New York City
Bevan, L. J. . . . . . Montclair, N. J.
Bilyeu, C. S. . . . . . New York City
Blackmore, G. G. . New York City
Blair, Alexander. . . Summit, N. J.
Blair, C. M. . . . New Haven, Conn.
Blakeslee, Clarence, New Haven, Conn.
Blakeslee, H. L. New Haven, Conn.
Blanchard, A. H. . New York City
Bleistein, B. J. . . . . Astoria, N. Y.
Boardman, C. S. . . . Buffalo, N. Y.
Boardman, W. H. . Newark, N. J.
Boes, F. C., West New Brighton, N. Y.
Bogart, John. . . . New York City
Bogert, C. L. . . . . . New York City
Bogue, V. G. . New Rochelle, N. Y.
Boniface, Arthur. Scarsdale, N. Y.
Bonnett, C. P., New Rochelle, N. Y.
Bontecou, Daniel, Kansas City, Mo.
Booth, G. W. . . . . . New York City
Booz, H. C. . . . . Ardmore, Pa.
Boucher, W. J. . . . New York City
Bouton, H. R. . . . . New York City
Boyd, R. W. . . . . . New York City
Brace, J. H. . . . . . New York City
Brackenridge, J. C. New York City
Bradley, F. E. . . . . New York City
Bramwell, G. W. . . New York City
Braslow, Barnett. . New York City

Breed, H. E.......Albany, N. Y.
Breitzke, C. F.....Boonton, N. J.
Brennan, J. G......Albany, N. Y.
Brennan, J. L....New York City
Breuchaud, Jules..New York City
Breuchaud, J. R...New York City
Briggs, J. A......New York City
Briggs, W. C....Brooklyn, N. Y.
Brooks, J. P......Potsdam, N. Y.
Brown, N. F.....Pittsburgh, Pa.
Brown, R. H.....New York City
Brown, T. E......New York City
Brush, W. W....Brooklyn, N. Y.
Bryan, C. W.New Rochelle, N. Y.
Bryson, Andrew.New Castle, Del.
Buel, A. W.......New York City
Buettner, O. G....New York City
Burdett, F. A.....New York City
Burpee, G. W.....New York City
Bush, E. W......Hartford, Conn.
Bush, Lincoln.East Orange, N. J.
Bushell, A. W..Jersey City, N. J.

Cahill, W. J.........Chicago, Ill.
Campbell, C. C..Philadelphia, Pa.
Cantwell, H. H..Montclair, N. J.
Carey, E. G..White Plains, N. Y.
Carle, N. A........Newark, N. J.
Carpenter, C. E...Yonkers, N. Y.
Carr, Albert..East Orange, N. J.
Case, G. O.......New York City
Case, J. F........New York City
Chambers, R. H..Flushing, N. Y.
Chase, C. F..New Britain, Conn.
Christian, G. L...New York City
Church, E. C.....New York City
Churchill, C. S.....Roanoke, Va.
Clapp, O. F.....Providence, R. I.
Clark, A. E..White Plains, N. Y.
Clark, G. H......New York City
Clarke, E. W..Pleasantville, N. Y.
Clarke, G. C., Richmond Hill, N. Y.
Clarke, St. John....Bogota, N. J.
Closson, E. S....Montclair, N. J.
Closson, W. G....Brooklyn, N. Y.
Codwise, E. B....Kingston, N. Y.
Codwise, H. R....Brooklyn, N. Y.
Cole, E. S.......Montclair, N. J.
Collins, T. E....Elizabeth, N. J.
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Conard, W. R..Burlington, N. J.
Condron, T. L.......Chicago, Ill.
Conger, A. A., Shelburne Falls, Mass.
Conklin, C. D., Jr., Cheltenham, Pa.
Conlon, F. J....Brooklyn, N. Y.
Connell, W. H..Philadelphia, Pa.
Connelly, J. A....New York City
Connor, E. H., Leavenworth, Kans.
Constant, F. H..Princeton, N. J.
Cooley, M. E..Ann Arbor, Mich.
Coombs, R. D..Ridgewood, N. J.
Coombs, S. E....Yonkers, N. Y.
Coomer, R. M..Sioux City, Iowa
Cooper, D. R.....New York City
Corthell, Elmer L...New York City
Coyne, H. L......New York City
Crandall, C. L......Ithaca, N. Y.
Crane, A. S......New York City
Craven, Alfred....Yonkers, N. Y.
Cresson, B. F., Jr., Jersey City, N. J.
Crocker, H. S......Denver, Colo.
Crocker, J. R.....New York City
Crooks, C. H.....New York City
Crosby, W. W....Baltimore, Md.
Cuddeback, A. W..Paterson, N. J.
Culyer, T. C., Purdy Station, N. Y.
Cummings, R. A..Pittsburgh, Pa.
Curtis, C. E........Ithaca, N. Y.
Curtis, F. S.......Boston, Mass.
Cushing, W. C....Pittsburgh, Pa.
Cutler, L. G....Waterbury, Conn.

Dakin, A. H., Jr..New York City
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Davis, C. E.....Philadelphia, Pa.
Dean, A. W........Boston, Mass.
Dean, Luther.....Taunton, Mass.
Desmond, T. C....New York City
Develin, R. G...Philadelphia, Pa.
Deyo, S. L. F.....New York City
Dibert, H. M........Troy, N. Y.
Diebitsch, Emil....Nutley, N. J.
Dillenbeck, Clark,
Philadelphia, Pa.
Dixon, G. G.........Kent, Ohio
Dodge, S. D......Mahwah, N. J.
Donham, B. C..Glen Ridge, N. J.
Doron, C. S......Brooklyn, N. Y.
Dorrance, W. T....Boston, Mass.
Dougherty, R. E.,
White Plains, N. Y.
Doyen, G. E......New York City
Drake, R. E......Brooklyn, N. Y.
Drayton, Newbold,
Penns Grove, N. J.
Dunlop, S. C......New York City
Durfee, J. J.....Brooklyn, N. Y.
Durham, H. W...New York City
Durham, Leicester,
Scarsdale, N. Y.
Duryea, Edwin, Jr.,
San Francisco, Cal.

Earle, Thomas......Steelton, Pa.
Easterbrook, F. J.,
New Haven, Conn.
Eckersley, J. O...New York City
Eddy, H. P........Boston, Mass.
Edmondson, R. S..New York City
Edwards, D. G......Hollis, N. Y.
Edwards, J. H.....Passaic, N. J.
Ellett, Tazewell, Jr.,
Richmond, Va.
Elwell, C. C..New Haven, Conn.
Ely, C. B........Harrisburg, Pa.
Ely, G. W., Jr....New York City
Emerson, K. B....New York City
Endemann, H. K..Jamaica, N. Y.
Endicott, M. T.Washington, D. C.
Ewing, W. W....Westfield, N. J.

Farley, M. M....New York City
Farnham, A. B...Pittsfield, Mass.
Farnham, Robert,
Philadelphia, Pa.
Farrington, H. P..New York City
Fellows, A. L.......Denver, Colo.
Ferguson, L. R..Philadelphia, Pa.
Fernandez, R. A..New York City
Ferris, F. E......New York City
Ferry, C. A...New Haven, Conn.
Files, T. H..White Plains, N. Y.
Firth, E. W......Jamaica, N. Y.
Fischer, Charles, Jr.,
New York City
Fisher, E. A....Rochester, N. Y.
Fisher, H. T....Scarsdale, N. Y.
Fitch, C. L.....New Orleans, La.
FitzGerald, Desmond,
Brookline, Mass.
Fletcher, Robert..Hanover, N. H.
Flinn, A. D......New York City
Ford, W. H.....Philadelphia, Pa.
Forgie, James....New York City
Fort, E. J.......Brooklyn, N. Y.
Foss, F. E........New York City
Foster, E. H......New York City
Fowler, C. W....New York City
Fox, W. F........New York City
Fraser, C. E.,
Westmount, Que., Canada
French, A. W...Worcester, Mass.
French, J. B......New York City
Frost, G. S......Brooklyn, N. Y.
Fuller, G. W......New York City
Fuller, W. B......New York City

Gailor, C. F......New York City
Gardiner, F. W....New York City
Gardiner, J. B. W.New York City
Gardner, Warren..New York City
Garfield, C. A...Bronxville, N. Y.

Gartensteig, Charles, New York City
Gaston, L. P....Somerville, N. J.
Gerhard, N. P...Scarsdale, N. Y.
Giesting, F. A. East Orange, N. J.
Gifford, G. E.....New York City
Gildersleeve, A. C. New York City
Giles, Robert.....New York City
Gillen, W. J......New York City
Gilman, Charles..Plainfield, N. J.
Gilmore, T. N....New York City
Goldmark, Henry. New York City
Goldsborough, J. B., Croton-on-Hudson, N. Y.
Gons, L. R......Brooklyn, N. Y.
Goodman, Benjamin, New York City
Goodman, Charles. New York City
Goodsell, D. B...Brooklyn, N. Y.
Gould, C. M......New York City
Govern, E. J.....New York City
Granbery, J. H...New York City
Greathead, J. F., White Plains, N. Y.
Green, B. L......Cleveland, Ohio
Green, F. M.......Berkeley, Cal.
Greene, Carleton..New York City
Greene, G. S., Jr., South Orange, N. J.
Greene, R. N......Darien, Conn.
Greenlaw, R. W..New York City
Greenman, R. S...Albany, N. Y.
Gregg, J. H. C...Brooklyn, N. Y.
Gregory, C. E...Mt. Kisco, N. Y.
Gregory, J. H....New York City
Greiner, J. E.....Baltimore, Md.
Griffith, W. F. R....Norfolk, Va.
Groat, B. F......Pittsburgh, Pa.

Haines, E. G., Richmond Hill, N. Y.
Hale, H. M......New York City
Hall, M. W......New York City
Hallock, J. C......Newark, N. J.
Halsey, W. H., Bridgehampton, N. Y.
Hamilton, E. P...New York City
Hammel, E. F....New York City
Hammel, V. F....New York City
Hammond, G. T..Brooklyn, N. Y.
Hanavan, W. L...New York City
Hanmer, H. J..Gloversville, N. Y.
Hansell, W. A.......Atlanta, Ga.
Harby, Isaac, Richmond Hill, N. Y.
Harding, H. S......Hollis, N. Y.
Haring, Alexander, New York City
Harrington, J. L., Kansas City, Mo.
Harris, B. B......New York City
Harte, C. R...New Haven, Conn.
Harwood, G. A..Scarsdale, N. Y.
Haskell, E. E.......Ithaca, N. Y.
Haskins, W. J....New York City
Hatch, F. N......New York City
Hatt, W. K.......Lafayette, Ind.
Hauck, William...New York City
Havens, W. W....New York City
Hawley, J. B..Fort Worth, Tex.
Hayden, E. C......Boston, Mass.
Hayes, R. B......Lexington, Ky.
Hazen, J. V......Hanover, N. H.
Healy, J. R......New York City
Heilbronner, L. C....Utica, N. Y.
Heiser, A. B.....Brooklyn, N. Y.
Heller, J. W., South Orange, N. J.
Herschel, Clemens, New York City
Hewes, V. H.....New York City
Higgins, J. W., Roselle Park, N. J.
Hilton, J. C.....Brooklyn, N. Y.
Hirai, Kikumatsu..New York City
Hodgdon, B. A...New York City
Hodgdon, F. W..Arlington, Mass.
Hodge, H. W....New York City
Hogan, J. P.....Brooklyn, N. Y.

Holbrook, A. R. . . New York City
Holden, C. A. . . . Hanover, N. H.
Holdredge, N. C. . New York City
Holland, C. M. . . Brooklyn, N. Y.
Holtman, Robert, Jr., Elmhurst, N. Y.
Hone, A. C. . . . . Rye, N. Y.
Honness, G. G. . . . Ashokan, N. Y.
Hoover, A. P. . . . . Paterson, N. J.
Horton, R. E. . . . . . Albany, N. Y.
Horton, Theodore. . Albany, N. Y.
Hosmer, R. H. . . . Harrisburg, Pa.
Houston, W. O. . . . Jackson, Mich.
Hovey, O. E. . . . . . New York City
Howard, J. L. . . . . . Boston, Mass.
Howard, L. T. . . . . New York City
Howe, C. E., Hastings-on-Hudson, N. Y.
Howell, W. A. . . . . . Newark, N. J.
Howes, D. W. . . . Brooklyn, N. Y.
Hoyt, J. C. . . . Washington, D. C.
Hubbard, Prévost, Washington, D. C.
Hudson, C. W., Upper Montclair, N. J.
Hudson, H. W. . . . New York City
Hudson, O. A. . San Antonio, Tex.
Huie, I. V. A. . . . . New York City
Hulsart, C. R. . . . . New York City
Hulse, S. C. . . . . Bedford, Pa.
Humphrey, R. L., Philadelphia, Pa.
Humphreys, A. C...New York City
Hunt, A. M. . . . . . New York City
Hunt, C. E. . . . . . New York City
Hunt, Charles Warren, New York City
Hunt, R. W. . . . . Chicago, Ill.
Hurd, H. L. . White Plains, N. Y.
Hurley, J. P. . . . Brooklyn, N. Y.
Hutchins, Edward, New York City
Hutchins, H. C. . Brooklyn, N. Y.
Hyde, H. E. . . . . Providence, R. I.

Immediato, Gerardo, New York City

Jackson, J. F. New Haven, Conn.
Jacobsen, H. P. R. New York City
James, C. A. . . . . . . Buffalo, N. Y.
James, R. L. . . Chapel Hill, N. C.
Jenkins, J. E. . . . . New York City
Jennings, J. E. . . Brooklyn, N. Y.
Joachimson, Martin, New York City
Johannesson, Sigvald, Upper Montclair, N. J.
Jonah, F. G. . . . . . . St. Louis, Mo.
Jonson, E. F. . . . . . New York City
Jordan, L. C. . . . . Brooklyn, N. Y.
Joseph, Jacob. . . . Brooklyn, N. Y.
Just, G. A. . . . . New York City

Kane, I. P. . . . . Gittings, Md.
Karner, W. J. . . . . New York City
Kaufman, Gustave. New York City
Keefer, C. H. Ottawa, Ont., Canada
Keith, H. C. . . . . . . New York City
Kelley, W. D. . . . . Yonkers, N. Y.
Kellogg, R. C. . . . Brooklyn, N. Y.
Kelly, C. W. . . New Haven, Conn.
Kelly, H. A. . . . Jersey City, N. J.
Khuen, Richard. . Pittsburgh, Pa.
Kilby, C. C. . . . New Haven, Conn.
Kimball, F. C. . . . . . Summit, N. J.
King, E. T. . . . . . Arrochar, N. Y.
King, P. S. . . . . . Wilmington, Del.
Kinney, W. M. . . . . . Chicago, Ill.
Kinsey, W. A. . . . . . Newark, N. J.
Kirkwood, H. C. . Flushing, N. Y.
Kittredge, G. W. . Yonkers, N. Y.
Kittredge, H. C. . Rochester, N. Y.
Knighton, J. A. . . . New York City
Knowles, Morris. . Pittsburgh, Pa.
Knox, S. B. . . . . . . New York City
Koch, O. H. S. . . . New York City
Kolb, H. J. . . . . . . New York City
Koop, L. D. . . . . . New York City
Kornfeld, A. E. . . . New York City

Krause, L. G...New Milford, Pa.
Krellwitz, D. W...New York City
Kuchar, F. M.....New York City

Lamson, W. M....New York City
Landers, C. S.....New York City
Landreth, O. H., Schenectady, N. Y.
Lange, T. F......New York City
Langthorn, J. S...New York City
Lannan, L. E..Mt. Vernon, N. Y.
Larsson, C. G. E..Plainfield, N. J.
Latimer, C. A....New York City
Lavis, Fred.......New York City
Law, W. H........Tiverton, R. I.
Lawrence, E. V...New York City
Lawrence, R. J..Philadelphia, Pa.
Leavitt, C. W....Hartsdale, N. Y.
Leffingwell, F. D., Upper Montclair, N. J.
Lehlbach, Gustav..Newark, N. J.
Lehman, H. M....Brooklyn, N. Y.
Leiser, Ferdinand, Jr., Brooklyn, N. Y.
Leland, O. M.......Ithaca, N. Y.
Leonard, H. R..Philadelphia, Pa.
Leser, Henry......New York City
Lesley, R. W......Haverford, Pa.
Lewis, L. H.......New York City
Lewis, N. P.......New York City
Lex, W. I.......Philadelphia, Pa.
Lindenthal, Gustav, New York City
Litter, F. J.......New York City
Lobo, Carlos......Brooklyn, N. Y.
Loewenstein, Jacob, New York City
Logan, W. S.....Arlington, N. J.
Longley, F. F.....New York City
Look,. M. J.Brown Station, N. Y.
Loomis, Horace, Mt. Vernon, N. Y.
Loweth, C. F........Chicago, Ill.
Lowinson, Oscar..New York City
Lucas, E. W. V. C.New York City
Lucas, G. L.......New York City
Lundie, John.....New York City
Lyon, G. J....Schenectady, N. Y.

MacCornack, C. W., Phœnixville, Pa.
MacFeeters, J. O., Glen Ridge, N. J.
MacGregor, R. A..New York City
Machen, H. B....New York City
Maclay, W. W.........Lee, Mass.
McCausland, C. P....Canton, Pa.
McConnell, I. W., Auburndale, Mass.
McCormack, E. W., Washington, D. C.
McDonald, Hunter, Nashville, Tenn.
McDowell, F. F...New York City
McLure, N. R...Phœnixville, Pa.
McMinn, T. J....Brooklyn, N. Y.
McMullen, R. W., New Canaan, Conn.
McNab, William, Montreal, Que., Canada
McNaugher, D. W., Pittsburgh, Pa.
McNulty, G. W...New York City
McPherson, R. H..New York City
Manley, L. B., West Roxbury, Mass.
Marburg, Edgar.Philadelphia, Pa.
Marsh, F. B....Crestwood, N. Y.
Marston, Anson......Ames, Iowa
Martin, E. S......New York City
Marx, C. D.......Palo Alto, Cal.
Mason, Francis...New York City
Masury, A. F.....New York City
Matlaw, I. S......New York City
Mayell, A. J......New York City
Mead, C. A., Upper Montclair, N. J.
Mead, D. W.......Madison, Wis.
Meadowcroft, William, New York City

Meeker, R. A....Plainfield, N. J.
Meem, J. C......Brooklyn, N. Y.
Megraw, W. A....Baltimore, Md.
Mehren, E. J.....New York City
Melins, L. L......New York City
Menke, William..New York City
Mercer, C. H.......Steelton, Pa.
Meriwether, Coleman, New York City
Merrill, R. H......Albany, N. Y.
Merriman, Mansfield, New York City
Merriman, R. M., Central Valley, N. Y.
Merryman, W. C..New York City
Metcalf, Leonard...Boston, Mass.
Miller, H. A.......Boston, Mass.
Miller, R. P......New York City
Miller, S. F.South Orange, N. J.
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Modjeski, Ralph...Portland, Ore.
Mogensen, O. E..Plainfield, N. J.
Moisseiff, L. S....New York City
Molitor, Frederic..New York City
Moncure, W. A.Philadelphia, Pa.
Monsarrat, C. N., Montreal, Que., Canada
Montfort, Richard.Louisville, Ky.
Moore, F. F....Hawthorne, N. Y.
Moore, W. H..New Haven, Conn.
Morrill, G. P..Bridgeport, Conn.
Morrison, H. J.Amsterdam, N. Y.
Morse, C. F..Good Ground, N. Y.
Morton, W. S.....New York City
Moss, W. B..Tompkinsville, N. Y.
Mozart, W. J....Westboro, Mass.
Muhs, F. R...San Francisco, Cal.
Muir, J. C......Bloomfield, N. J.
Muirhead, J. H. H.New York City
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Musson, E. F.....Norwich, N. Y.
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Myers, E. T. D., Jr.Richmond, Va.
Myers, J. H..White Plains, N. Y.

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Norton, G. H......Buffalo, N. Y.

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Ockerson, J. A....St. Louis, Mo.
Odell, F. S....Port Chester, N. Y.
O'Hara, M. J......Hudson, N. Y.
Okeson, W. R......Orange, N. J.
Olmsted, H. W., Pleasantville, N. Y.
Orr, Alexander.Gloversville, N. Y.
Ott, S. J.......Rutherford, N. J.
Owen, James....Montclair, N. J.

Paddock, H. C....Caldwell, N. J.
Pagon, W. W.....Baltimore, Md.
Paine, H. A....Wilmington, Del.
Palmer, S. B.....Norwich, Conn.
Parker, C. J......New York City
Parker, J. L......New York City
Parlin, R. W.....Brooklyn, N. Y.
Parmley, W. C., Upper Montclair, N. J.
Parsons, H. de B..New York City
Parsons, R. S.....New York City
Peck, L. F.......Hartford, Conn.
Pegram, G. H....New York City
Peirce, V. M..Washington, D. C.
Pellissier, G. E., Springfield, Mass.
Pelz, C. E........New York City
Pemoff, J. J......New York City
Perkins, W. W. C.Conneaut, Ohio
Perrine, George...New York City
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Phillips, A. E. . Washington, D. C.
Pickersgill, W. C. Providence, R. I.
Pitkethly, D. L. . Brooklyn, N. Y.
Pohl, C. A. . . . . New York City
Pollock, C. D. . . . . New York City
Pommerer, R. W., White Plains, N. Y.
Pond, F. H. . . . . . Brooklyn, N. Y.
Poole, C. A. . . . . . Rochester, N. Y.
Poore, H. C. . . . . . Braintree, Mass.
Porter, G. F., Montreal, Que., Canada
Porter, J. E. . . . . . Yonkers, N. Y.
Porter, J. M. . . . . Easton, Pa.
Pratt, A. H. . White Plains, N. Y.
Pratt, F. E. . . . Glen Ridge, N. J.
Preston, H. W. . . . . Elmira, N. Y.
Price, F. O. . . . . . Brooklyn, N. Y.
Price, P. L. . . . . Hempstead, N. Y.
Prichard, H. S. . . . Pittsburgh, Pa.
Priest, B. B. . East Orange, N. J.
Proctor, R. F. . . . . Baltimore, Md.
Prout, H. G. . . . . Nutley, N. J.

Quimby, H. H. . Philadelphia, Pa.
Quimby, J. H. . Pearl River, N. Y.
Quincy, Edmund. . New York City
Quinn, M. F. . . . . . New York City

Ralston, J. C. . . . . Spokane, Wash.
Rankin, E. S. . . . . . Newark, N. J.
Reeves, W. F. . . . . New York City
Reichmann, A. F. . . . Chicago, Ill.
Rennell, H. H. . . . New York City
Requardt, G. J. . . . Baltimore, Md.
Reynolds, L. C., Rockville Center, N. Y.
Rice, G. S. . . . . New York City
Richards, N. A. . . . New York City
Richardson, J. D. . Corona, N. Y.
Richardson, R. D. . . Scranton, Pa.
Richmond, J. P. W., New York City
Ridgway, Robert. . New York City
Riedel, J. C. . . . . . Brooklyn, N. Y.
Riegler, L. J. . . . . . Ben Avon, Pa.
Rights, L. D. . . . . . New York City
Ripley, H. L. . . . . . Boston, Mass.
Ripley, Joseph. . . . . Albany, N. Y.
Robbins, A. A. . . . New York City
Robbins, D. W. . . . . . Utica, N. Y.
Robbins, F. H., White Plains, N. Y.
Roberts, R. F. . . . . . Nutley, N. J.
Robinson, E. F. . . . New York City
Robinson, E. W. . . New York City
Robinson, G. L. . . . New York City
Robinson, H. D. . . New York City
Rogers, A. W. . . . Rochester, N. Y.
Rogers, E. H. West Newton, Mass.
Rogge, J. C. L. . . . Katonah, N. Y.
Rothrock, W. P. . . New York City
Ruckes, J. J., Jr. . New York City
Rumery, R. R. . . . . New York City
Rust, H. P. . . . . New York City
Ryan, M. H. . . . . . . New York City

Sackett, R. L. . . State College, Pa.
Sacks, S. I. . . . . . Philadelphia, Pa.
Sanborn, F. B., Tufts College, Mass.
Sanborn, J. F. . . . . . . Nutley, N. J.
Sanford, H. C. . . . . New York City
Saville, C. M. . . . . Hartford, Conn.
Sayers, E. L. . . . Hackensack, N. J.
Schaeffer, Amos. . . New York City
Scheidenhelm, F. W., New York City
Schmidt, H. H. . . Brooklyn, N. Y.
Schneeweiss, A. E. . Newark, N. J.
Schneider, E. J., San Francisco, Cal.
Schreiber, J. M. . . . Newark, N. J.
Schwarze, C. T. . . . New York City
Seabury, G. T. . Providence, R. I.
Seage, C. E. New Brighton, N. Y.
Seaman, H. B. . . . New York City
Searight, G. P. . . . New York City
Searle, C. D. . . . . . New York City
Searle, L. F. . . . . Kingston, N. Y.

Seaver, Clifford....Bayside, N. Y.
Selby, O. E.....Cincinnati, Ohio
Serber, D. C.....New York City
Shailer, R. A....Brookline, Mass.
Shaner, H. L.....Lynchburg, Va.
Shaughnessy, C. S.Brooklyn, N. Y.
Shaw, G. H....Washington, D. C.
Shedd, G. G...Manchester, N. H.
Shellenberger, L. R.,
Bayonne, N. J.
Sherman, H. J....Camden, N. J.
Sikes, Z. H.......Yonkers, N. Y.
Sitt, W. T........New York City
Skillin, E. S....Glen Ridge, N. J.
Skinner, B. B....New York City
Skinner, F. W.,
Tompkinsville, N. Y.
Skinner, J. F....Rochester, N. Y.
Sloan, S. A.....Philadelphia, Pa.
Smith, Augustus..Bayonne, N. J.
Smith, C. E.,
West New Brighton, N. Y.
Smith, C. W....Westwood, N. J.
Smith, E. F......Brooklyn, N. Y.
Smith, E. M.........Chicago, Ill.
Smith, E. N........Nutley, N. J.
Smith, H. E..Binghamton, N. Y.
Smith, J. R......Phœnixville, Pa.
Smith, J. W......New York City
Smith, W. F......Valhalla, N. Y.
Smoley, C. K......Scranton, Pa.
Snow, J. B....Woodhaven, N. Y.
Snow, J. P.........Boston, Mass.
Snyder, G. D.....New York City
Soest, H. C.......New York City
Solomon, G. R.......Atlanta, Ga.
Soper, G. A.......New York City
Spear, P. H.,
Hastings-on-Hudson, N. Y.
Spear, W. E......New York City
Spencer, C. B.....New York City
Spencer, Herbert..New York City
Splitstone, C. H.,
East Orange, N. J.
Spofford, C. M......Boston, Mass.
Sprague, E. L., Jr. Valhalla, N. Y.
Staniford, C. W..Brooklyn, N. Y.
Stark, C. W......New York City
Starr, H. H.......New York City
Stearns, F. LeRoy. New York City
Stearns, F. Lincoln,
Scarsdale, N. Y.
Stearns, R. H..Providence, R. I.
Stein, J. B.......Brooklyn, N. Y.
Steinman, D. B...New York City
Stern, E. W......New York City
Stickle, H. W....Brooklyn, N. Y.
Stiles, A. I.......New York City
Stoddard, G. C...New York City
Stowitts, G. P....Yonkers, N. Y.
Strachan, Joseph. Brooklyn, N. Y.
Strong, M. R.....New York City
Stuart, F. L......Baltimore, Md.
Sullivan, J. F....New York City
Sullivan, J. G.,
Winnipeg, Man., Canada
Sutton, C. W.....Yonkers, N. Y.
Sutton, Frank..Washington, D. C.
Swain, G. F........Boston, Mass.
Swezey, E. C....Brooklyn, N. Y.
Swindells, J. S...Brooklyn, N. Y.

Taber, G. A......Brooklyn, N. Y.
Taft, J. R........New York City
Talbot, A. N.........Urbana, Ill.
Talbot, Earle....Englewood, N. J.
Talbot, K. H......Pittsburgh, Pa.
Tallman, Leroy...Brooklyn, N. Y.
Tallman, P. B.,
East Orange, N. J.
Terry, A. H....Bridgeport, Conn.
Thomas, C. D....Brooklyn, N. Y.
Thomas, W. J....New York City
Thomes, E. H.....Jamaica, N. Y.
Thompson, S. C...New York City
Thompson, S. E.,
Newton Highlands, Mass.
Thomson, Alexander, Jr.,
Walden, N. Y.
Thomson, John...New York City

Thomson, S. F...Brooklyn, N. Y.
Thomson, T. K....New York City
Thomson, W. B..Cleveland, Ohio
Tidd, A. W..White Plains, N. Y.
Tillson, G. W....Brooklyn, N. Y.
Tompkins, E. De V., New York City
Tompson, G. M..Wakefield, Mass.
Townsend, C. McD. St. Louis, Mo.
Trautwine, J. C., Jr., Philadelphia, Pa.
Tretter, G. A.......Roanoke, Va.
Tribus, L. L......New York City
Triest, W. G......New York City
Trimpi, A. L..East Orange, N. J.
Trout, C. E.......New York City
Tucker, L. W....Freeport, N. Y.
Turneaure, F. E...Madison, Wis.
Turner, D. L......New York City
Tuska, G. R......New York City
Tuttle, A. S.......New York City
Tyson, A. H....Glen Ridge, N. J.

Ungrich, M. J.....New York City
Upton, Joseph....Flushing, N. Y.

Vail, E. M.......Plainfield, N. J.
Vallely, W. P.....New York City
Value, B. R......New York City
Vandervoort, B. F. Brooklyn, N. Y.
Van Horne, J. G..New York City
Van Keuren, C. A., Jersey City, N. J.
Van Norden, E. M., Brooklyn, N. Y.
Van Suetendael, A. O., Albany, N. Y.
Van Winkle, E. B. New York City
Vaughan, L. B...Kingston, N. Y.
Vincent, J. I.....New York City
Vinton, T. M.....New York City
Vogel, J. L.....Jersey City, N. J.
Vroman, Guy...Larchmont, N. Y.

Wadsworth, J. E..New York City
Wagner, John, Jr., Phœnixville, Pa.
Wagner, S. T...Philadelphia, Pa.
Wahlman, Petrus. New York City
Wait, B. H..Poughkeepsie, N. Y.
Waite, D. C......Brooklyn, N. Y.
Wallace, J. F.....New York City
Warnock, W. H..Edgemere, N. Y.
Watkins, F. W., White Plains, N. Y.
Watters, G. L.....Bethlehem, Pa.
Webster, A. L....New York City
Wegmann, Edward. Yonkers, N. Y.
Wells, C. E.......Yonkers, N. Y.
Wells, G. E....Naugatuck, Conn.
Wendt, E. F..Washington, D. C.
Werbin, I. V.....New York City
Weymouth, Aubrey, Flushing, N. Y.
Wheatcroft, H. B., Jr., Newark, N. J.
Wheeler, W. S....New York City
Whiskeman, J. P. New York City
White, Lazarus...New York City
Whitman, A. B....Baltimore, Md.
Whitson, A. U....Flushing, N. Y.
Wickersham, J. H. Lancaster, Pa.
Wiggin, E. W..New Haven, Conn.
Wiggin, T. H....Scarsdale, N. Y.
Wilcock, Frederick, Brooklyn, N. Y.
Wild, H. J..........Chester, Pa.
Wiley, W. H......New York City
Wilkerson, T. J...Pittsburgh, Pa.
Williams, C. G...Plainfield, N. J.
Williams, G. D....Albany, N. Y.
Williams, G. S. Ann Arbor, Mich.
Williams, J. P. J. New York City
Williams, M. W....Albany, N. Y.
Williamson, S. B. New York City
Wilmot, James....New York City
Wilmot, Sydney..New York City
Wilson, P. H.........Devon, Pa.
Wilson, William..New York City

Wilson, W. L.....Bethlehem, Pa.
Wilson, W. T.....New York City
Winslow, F. I......Boston, Mass.
Winsor, F. E...Providence, R. I.
Winsor, G. A. Pleasantville, N. Y.
Wise, C. R.........Passaic, N. J.
Witmer, F. P. East Orange, N. J.
Woehrlin, G. J..Brooklyn, N. Y.
Wolcott, C. S......Hornell, N. Y.
Wolfe, F. C....Bridgeport, Conn.
Wolfe, F. G........Scranton, Pa.
Wolff, H. H.......Seattle, Wash.
Wolff, R. B......Glendale, N. Y.
Woodcock, H. W. Brooklyn, N. Y.
Worcester, J. R....Boston, Mass.
Wright, F. J......Paterson, N. J.
Wulff, E. J.....Tarrytown, N. Y.
Wyckoff, C. R...Hartsdale, N. Y.
Wyman, A. M., Long Island City, N. Y.

Yappen, A..........Chicago, Ill.
Yates, W. H......New York City
Yereance, A. W., South Orange, N. J.
Yereance, W. B., South Orange, N. J.
Young, C. G......New York City

SOCIETY ITEMS OF INTEREST

Suggested Change of Society Headquarters

To the Corporate Members,

American Society of Civil Engineers:*

An offer has been made to this Society which your Board considers to be one, the acceptance or rejection of which is perhaps the most important question which has ever come before the Society.

It will be remembered that 12 years ago by a letter-ballot the Corporate Members of the Society decided not to accept, in its behalf, a quarter interest in the gift of Mr. Andrew Carnegie of $1 050 000 to be expended on a home for the four National Societies.

Subsequent to this decision Mr. Carnegie gave the amount mentioned to the three other Societies, and at No. 29 West 39th Street there was erected a thirteen-story building for their occupancy. This money was expended entirely upon the building, the three Founder Societies furnishing the land.

In 1896 this Society purchased two lots on West 57th Street and erected its own home, and, subsequent to the decision not to accept Mr. Carnegie's offer, purchased an additional lot and erected an addition to the original building thereon, so that the present home of the Society consists of a four-story and basement building of 75 ft. frontage, and an average depth of 110 ft. 7 in.

The advisability, even the necessity, of greater co-operation between the various branches of the Engineering Profession for the general good has been a frequent topic of discussion among individuals for the last few years. One of these discussions resulted in an informal meeting of a number of gentlemen interested in this subject on June 9th, 1915. At this conference there were present the President and Vice-President of the United Engineering Society, the President of the American Institute of Mining Engineers, the President-elect of the American Institute of Electrical Engineers, a Past-President of the American Society of Mechanical Engineers, and the Secretary of the American Society of Civil Engineers.

Following this conference correspondence between the President of the United Engineering Society and the President of the American Society of Civil Engineers led to the following communication:

"Dr. Charles D. Marx, *President,*
American Society of Civil Engineers,
220 W. 57th Street, New York.

"My Dear Sir:

"Referring to my letter of June 10th I have the honor to advise you that the following Resolution was unanimously passed by the

* This communication was issued February 1st, 1916, by the Board of Direction to all Corporate Members.

United Engineering Society at its meeting on June 24th and I was directed to lay it before you:

"'*Resolved,* That out of its desire to welcome the American Society of Civil Engineers into the fraternity of the Founder Societies and with a sense of the increased dignity and usefulness to the engineering profession which this adherence of the American Society of Civil Engineers would contribute, the United Engineering Society hereby desires to express the sentiment in favor of coalition which has been growing, and to invite the American Society of Civil Engineers to consider entering the United Engineering Society as an additional Founder Society; and the President is authorized to appoint a Committee to confer with any corresponding Committee of the American Society of Civil Engineers in the formation of a tentative plan which if this invitation is accepted can be referred on the part of the United Engineering Society to the governing bodies of the Founder Societies for their action.'

"In accordance with this Resolution I have appointed as the Conference Committee referred to Vice-President Charles F. Rand, Chairman, Dr. Alexander C. Humphreys and Mr. H. H. Barnes, Jr., and I am forwarding this letter in care of Dr. Hunt at the Headquarters of the American Society of Civil Engineers, sending a duplicate to your California address.

"Believe me, Dear Sir, with hope for favorable action on the part of the American Society of Civil Engineers,

"Very respectfully yours,

"GANO DUNN,
President."

In order that the membership may not be confused, it should be explained that the United Engineering Society was incorporated for the purpose of acting for the three Founder Societies, viz.: the American Institute of Mining Engineers, the American Society of Mechanical Engineers, and the American Institute of Electrical Engineers, in all matters relating to their property holdings, and that this original suggestion and the subsequent offer made by the United Engineering Society acting for these three Founder Societies have been confirmed by each of the Societies separately.

A Conference Committee as suggested in the above letter consisting of Vice-President Clemens Herschel, Past-Director Robert Ridgway, and Secretary Chas. Warren Hunt, was appointed by President Marx, and after careful investigation of the whole question, reported to your Board September 20th, 1915. At a meeting of the Board November 9th, 1915, the Committee was enlarged by the addition of Vice-President Charles F. Loweth and Past-Presidents John A. Ockerson, George F. Swain, and Hunter McDonald. This Committee has been going into the whole matter thoroughly, and has been furnished by the Committee of the United Engineering Society with all available data upon which a judgment of the situation, so far as business arrangements are concerned, must be based. The present communication is based on the unanimous report of that Committee.

There have been two offers made which may be briefly stated as follows:

(A) That a two and one-half story addition be made to the United Engineering Society Building at a cost estimated at $225 000, and not to exceed $250 000. That the American Society of Civil Engineers shall pay for this addition if the cost does not exceed the latter figure, and if said cost does exceed $250 000, the additional expense shall be borne by the United Engineering Society.

That the American Society of Civil Engineers shall then become an equal owner in the whole enlarged property on the same terms as each of the three present Founder Societies, and occupy as much space as it may need on the two floors to be added.

(B) That the American Society of Civil Engineers become one of the Founder Societies by the payment into the United Engineering Society Treasury of a sum of money equal to that which each of the three Founder Societies has paid, the estimated amount being $240 000. This sum to be invested in interest-bearing bonds and held for the benefit of the United Engineering Society, of which the American Society of Civil Engineers would then become a part. That these bonds would be available in case it should later be found necessary to enlarge the building; otherwise, the income would be available for the activities of the United Engineering Society as the Founders may determine. The American Society of Civil Engineers to occupy such part of the sixth and seventh floors as it needs. (See Appendix B).

The property of the United Engineering Society now stands free and clear of all debt, and there is a Reserve Fund of $70 160.89 for amortization of the building and for depreciation and repairs, and if the first offer is accepted this Society will have an equal ownership in the entire enlarged property with the three other Societies for practically the same amount of cash which each of them has expended up to the present time.

It will be observed that if offer "A" is accepted the present building will be enlarged so as to accommodate in a large and up to date stack-room the proposed great Research Library in addition to providing enough additional space for the use of our Society on the two top floors, thus leaving plenty of room for the accommodation of other smaller scientific and technical organizations, many of which now occupy space in the building.

If offer "B" is accepted many of these present occupants will necessarily have to seek other quarters, and, as the work of the four Societies grows, eventually there will be room only for the four Founder Societies. It is true that the proposed addition may be made when necessary but in the meantime the building will have lost the character of a Headquarters for all professional activities, and will be only the home of the four Founder Societies.

It is evident, therefore, that the acceptance of offer "A" will carry out more fully the broad fundamental idea which underlies the whole proposal.

There can be no question as to the ability of the four Societies to handle the larger of the two propositions from the beginning.

In order to ascertain from a reliable source what quick assets the Society may have with which to operate, a valuation of the present property of the American Society of Civil Engineers was made by the Real Estate Board of New York, which report is as follows:

"A careful examination of the property having been made, the present value of land and improvements is appraised at three hundred and twenty-five thousand ($325 000) dollars.

Value of land	$290 000
Value of building	35 000
Total valuation	$325 000"

Annexed to this is the following statement:

"The building is a four-story and basement brick and stone building, about 20 years old built for the American Society of Civil Engineers. It is in excellent condition and is adaptable only for the use of a club or possibly a restaurant."

It will be noticed that in this report the present value of the ground on which the Society House is built is given as $290 000. Its total cost to the Society, including legal fees, etc., was $185 406.20. Attention is called to the fact that the cost of the building, including legal expenses, etc., has been $174 775.64, and that its estimated value by the Real Estate Board of New York is only $35 000. Adding the cost of the land to the cost of the building, the total cost of the Society's real property at the present time has been $360 181.84, and it is only proper to say that the present House of the Society is, in the opinion of many members, adequate for its present needs, and could not be duplicated at the present date at the figures given. In other words, that the Society could not at the present date duplicate its plant for less than $475 000.

Assuming, however, that the property could not be sold quickly at more than the amount named by the Real Estate Board, and adding the amount which the Society now has invested in bonds over and above the amount of the present mortgage, it would appear that a very conservative estimate of the available assets which could promptly be turned into cash is $365 000. ($90 000 is now invested in bonds and the present mortgage indebtedness is $50 000.) Should therefore the Society accept offer "A" it could make full payment and have between $115 000 and $140 000 in the treasury, and would then own a one-quarter interest in the enlarged property of the United Engineering Society, the cost of which added to the accumulated reserve fund already mentioned will amount to $1 967 332; one-quarter of which is $491 833.

A careful investigation of the cost of operation and maintenance at the present home of the Society, and for an equal accommodation in the 39th Street Building, shows that this item need not be considered, there being no material difference in the annual cost of operation.

Your Board does not think it necessary to burden this Report with details of figures which have to be gone into with great care in order to arrive at correct results, but all of the statements of fact that are made in this Report may be relied upon as having been arrived at after the most careful and thorough investigation.

Your Board also wishes to suggest that, as there would be no great haste about selling the property of the Society, a sum considerably more than that estimated by the New York Real Estate Board may be secured.

The Libraries of the three Founder Societies, the American Institute of Mining Engineers, the American Society of Mechanical Engineers, and the American Institute of Electrical Engineers, are now combined, and are being operated by the United Engineering Society, and the addition of the Library of the American Society of Civil Engineers would result in a collection of engineering books aggregating approximately 150 000 volumes which would form the nucleus for one of the greatest Technical Libraries of the world, which when properly housed, catalogued, and maintained, would furnish an equipment for the carrying on of research work which could not be excelled. There is reason to believe that should such a combination be formed, funds to a large amount would be forthcoming for the endowment and maintenance of such a Research Library.

For a number of years it has been quite evident to those who have been close to the activities of Engineering Societies that a closer co-operation is needed especially along the lines of the general welfare of the Profession. Matters have come up from time to time which have resulted in the appointment of a Joint Committee (which is now in existence) to consider and to report back to the Governing Bodies of each of the Societies on any question brought to its attention which affects the Profession as a whole, and Joint Committees of all the Societies have also done much work in matters relating to proposed

Legislation in various States on the Licensing or Registration of Engineers, and in connection with the work of the recent Constitutional Convention of the State of New York. In addition to this all four of these National Societies have been represented for more than nine years on the John Fritz Medal Board of Award, and they are now all equally represented on the Engineering Foundation Board, which was founded by the generous gift of Mr. Ambrose Swasey. It is largely through such joint committees made up of members of each Society, clothed with the proper authority, that the general welfare of the Engineering Profession can be safeguarded and promoted.

It is the belief of your Board, after repeated conferences with the officers and Conference Committee of the United Engineering Society, that such Committees, which now must be more or less disjointed in their action, may be made more permanent, and therefore represent more authoritatively the Engineering Profession in matters relating to the status of the Profession generally, and its individual members, both financially and socially, and in a manner which it is not possible for any one purely professional organization to accomplish. The need for such authoritative representation is clearly indicated by the attitude of many members of our Society, as well as of the other National Organizations.

The Engineering Profession needs co-operation along these lines, there being no coherence between individuals, or groups of individuals, and it is one of the purposes of this movement to strengthen the bonds of brotherhood which should exist between all Engineers.

It is fully recognized that to accomplish anything of magnitude sacrifices often must be made, and that to a certain extent, at least as far as property ownership is concerned, our Society, if the offer is accepted, will give up a certain amount of independence. This does not, however, go any further than the property consideration, as it is not proposed in any way to change the methods of control of each individual Society. Closer association with men of similar training, though working along the lines of different specialties, should tend to broaden the views of those who come within the sphere of such influence.

Our Society now has a fine home, adequate, in the opinion of many members, for its present needs, and, as they think, capable of such enlargement as may be rendered necessary during the next 15 or 20 years. On the other hand, if the proposed enlargement of the United Engineering Society Building is carried out, there will be plenty of room for the four Founder Societies, and for a large number of other organizations not strong enough to own their own headquarters, and thus there will be in the City of New York a representative American Engineering Headquarters where any Engineer may go with the certainty of meeting his professional brothers.

In such a project as this there are many details to be considered, and while much study has been given to the whole question by your Board, in its execution there will doubtless be many matters of adjustment which cannot be foreseen.

The main question, however, which must be decided by the membership of the Society is whether the offer of the United Engineering Society shall be accepted.

Your Board submits the following questions to letter-ballot of the Corporate Membership, without recommendation, believing that every member, after careful consideration of the matter presented in this report, should vote upon them as his individual judgment dictates.

These questions are:

First: Shall the American Society of Civil Engineers accept one of the offers made in behalf of the American Institute of Mining Engineers, the American Society of Mechanical Engineers, and the American Institute of Electrical Engineers, through the United Engineering Society?

Second: If the result of this ballot is in the affirmative,

(*a*) Do you favor Plan "A" as outlined?

(*b*) Do you favor Plan "B" as outlined?

(*c*) Do you favor leaving the question of the plan to be accepted in the hands of the Board of Direction?

Enclosed herewith is a Ballot on these questions, with two Envelopes. Ballots may be enclosed and sealed in the smaller, and mailed in the larger. To make the vote valid, however, the signature of the Corporate Member must be endorsed on the outer envelope. The Ballot must be returned on or before June 15th, 1916. The canvass will be conducted by the Board, and the result reported to the Business Meeting of the Annual Convention.

There will also be mailed to each member a pamphlet, kindly furnished by the United Engineering Society, descriptive of the building, joint ownership and occupancy of which is offered, as it stands to-day.

By order of the Board of Direction,

CHAS. WARREN HUNT,

Secretary.

NEW YORK, FEBRUARY 1ST, 1916.

Appended to this Report for the information of the membership are the following:

(A) Letter of August 23d, 1915, signed by Messrs. Charles F. Rand, H. H. Barnes, Jr., and Alex. C. Humphreys, referring to offer "A".

(B) Letter of October 28th, 1915, signed by Messrs. Charles F. Rand, H. H. Barnes, Jr., and Alex. C. Humphreys, referring to offer "B".

(C) Statement of cost of United Engineering Society Property.

(D) Statement of cost of the Property of the American Society of Civil Engineers.

APPENDIX

ACCOMPANYING REPORT OF BOARD ON PROPOSED CHANGE OF HEADQUARTERS OF AMERICAN SOCIETY OF CIVIL ENGINEERS DATED NOVEMBER 24th, 1915

(A)

29 West 39th Street,
New York, N. Y., August 23, 1915.

Mr. Clemens Herschel, *Chairman,*
Mr. Charles Warren Hunt,
Mr. Robert Ridgway,
Special Committee of American Society of Civil Engineers.

Gentlemen:

On July 6th we submitted to you a memorandum relating to the project of arranging for the American Society of Civil Engineers to become a Founder Society of the United Engineering Society. At the time the memorandum was submitted, we had before us the estimates of architects and builders to the effect that the changes in the Engineers Building as contemplated would cost approximately $300 000. Since that time, after an opportunity for consultation with the officers of the various Societies, we have become aware that all proper requirements can be met by the expenditure of a somewhat smaller sum.

The original plan and estimate provided for the addition of three floors to the building, two for offices and one for library uses. Present plans contemplate two floors for offices and a mezzanine floor for library storage.

We now have estimates from architects and contractors indicating that the sum of $225 000 will be sufficient. To this, for safety, this committee considers it wise to add $25 000 for contingencies, making the total $250 000.

In our memorandum of July 6th, we suggested that whatever it costs to enlarge the building the Civil Engineers should pay.

We would now propose that if the cost is less than $250 000, the difference should inure to the benefit of the Civil Engineers. We would also propose that U. E. S. guarantee that the improvements, provided no radical change is made in present plans, shall not cost to exceed $250 000.

Upon the approval of this arrangement by the Civil Engineers, the original Founder societies would offer to share with the Civil Engineers the amount of the original Carnegie gift.

Hoping that the suggestions will meet with favor, we are

Very truly yours,

Charles F. Rand,
H. H. Barnes, Jr.,
Alex. C. Humphreys.

(B)

NEW YORK, October 28, 1915.

MR. CLEMENS HERSCHEL, *Chairman,*
MR. CHARLES WARREN HUNT,
MR. ROBERT RIDGWAY,
Special Committee,
American Society of Civil Engineers.

GENTLEMEN:

Referring to our communications of July 6th and August 23rd, relating to the proposal that the American Society of Civil Engineers should become a Founder Society of the United Engineering Society, you will recall that one of the suggestions contained in our letter of July 6th was that the Civil Engineers and their library might be accommodated in the existing building for some considerable time without material change therein.

We desire again to refer to this suggestion, which in our opinion merits most careful consideration on the part of all concerned.

Many of the Trustees of the United Engineering Society, and, we think, some of the members of your Society who have considered the question are of the opinion that we should look forward to the time when the building would be used exclusively by the Civil Engineers, Mining Engineers, Mechanical Engineers and Electrical Engineers, and the Library, without any associate societies in the building. These societies of mining, electrical and mechanical engineers are at the present time very handsomely housed in the building on the ninth, tenth and eleventh floors thereof. The sixth, seventh and eighth floors are partially occupied by associate societies who could, if necessary, be gradually provided for in adjoining buildings. Some could be retained until such time as the four great societies require the entire building.

The Library has now assigned to it the twelfth and thirteenth floors, where we have ample space for upward of a quarter of a million volumes.

The combined libraries of the three old Founder Societies and the United Engineering Society now contains fifty-five thousand bound volumes, fifteen thousand unbound volumes and pamphlets, and five thousand specifications, maps, etc., total seventy-five thousand. We understand that the library of the Civil Engineers contains twenty-five thousand bound volumes, forty-eight thousand unbound volumes and pamphlets, and thirteen thousand specifications, maps, etc., total eighty-six thousand.

As there are many duplications which could be eliminated if and when the Civil Engineers join, it has been estimated that the number of books added might not exceed 10 000, and that there would still be space in the existing library quarters for from 100 000 to 150 000 accessions which would probably be sufficient for several years to come.

It is quite possible that we might find it desirable to provide for still further accessions to the Library and for enlarged activities thereof, in which event it would be possible, with the friendly co-operation of the Founders, that a rearrangement of the floors could be effected and free the eleventh floor so as to add that floor to the library.

In our opinion the sixth floor of the building is the most desirable of any, the ceilings being materially higher than any other office floor. This is because the floor was originally built and used for lecture rooms. It has now been divided for offices. This sixth floor and the seventh floor, or so much thereof of both as necessary, might very well be used as the headquarters of the American Society of Civil Engineers.

In our opinion the present building has ample accommodations for the four Societies and the library, and for space for all to expand and we think it is possible that further conference may develop some economies of space, such, for example, as having only one or two Board rooms instead of four, and perhaps other similar arrangements which may indicate that the building is actually too big.

In case, therefore, you consider the foregoing suggestions, we would think that the following arrangement might be proper:

That the American Society of Civil Engineers if and when it becomes a Founder Society, should arrange to pay into the United Engineering Society treasury a sum of money equal to that which each of the three Founder Societies has paid. We estimate this sum at Two Hundred and Forty Thousand Dollars. This sum to be invested in interest-bearing bonds and held for the benefit of the United Engineering Society, of which the Civil Engineers would then be a part. These bonds would be available in case it should later be found necessary to enlarge the building; otherwise, the income would be available for the activities of the United Engineering Society as the Founders might determine.

May we suggest a careful examination of all parts of the existing building by the members of your committee, in order that its present facilities and possibilities may be clearly understood.

Very truly yours,

Charles F. Rand,
H. H. Barnes, Jr.,
Alex. C. Humphreys.

(C)

COST OF THE THIRTEEN-STORY BUILDING

OF THE

UNITED ENGINEERING SOCIETY,

29 West 39th Street.

Original expenditure of the Building Committee........	$1 060 039.85
Paid for the land....................................	540 000.00
Paid brokers, and expenses obtaining land..............	24 000.00
Paid for additional elevator, storage facilities, toilets, etc., etc..	23 131.31
Accumulated repair and depreciation fund............	70 160.89
Total	$1 717 332.05

(D)

COST OF PROPERTY AND BUILDING

OF THE

AMERICAN SOCIETY OF CIVIL ENGINEERS,

220 West Fifty-seventh Street.

Lots	$185 406.20
Building	174 775.64
Total	$360 181.84

Report of Committee of the Board of Direction on the Licensing of Architects, Etc.

TO THE BOARD OF DIRECTION,
AMERICAN SOCIETY OF CIVIL ENGINEERS.

GENTLEMEN.—Your Committee, appointed to consider and report upon the question of the Licensing of Architects, submits the following report:

The American Institute of Architects has a Standing Committee on Legislation, and most of the State Chapters of the Institute have similar Committees. Through these agencies there has been effected in several States laws regulating and licensing the practice of Architecture; and similar legislation has lately been actively proposed in several States, notably Iowa, Pennsylvania, Washington, Ohio, Wisconsin, Kentucky, Texas, Oregon, and Oklahoma.

All these laws, as also all those heretofore proposed, make illegal the construction of buildings, except upon the plans and specifications prepared by licensed architects. These laws define buildings so broadly and comprehensively as to include practically every enclosed structure; and under them only licensed architects could legally design even the simplest structures, including those generally designed by Engineers.

It is not generally conceded that the safety and welfare of the public are best safeguarded by the licensing of the several professions and crafts. But if such be the case, it can be so only when those licensed include all who by training and experience are qualified.

The Architectural License laws, now in force and proposed, work serious hardships upon Engineers. They cannot legally plan many structures for which they are at least as competent as Architects, and many others for which they may be more competent; even the minor and appurtenant building details incident to varied and extensive construction works of large magnitude are excluded.

The Architectural License law of Illinois, passed several years ago, and enforced of late with increased rigidity, resulted in placing the Engineers in that State engaged in structural designing in an intolerable position. With great difficulty they have lately secured legislation providing for the licensing of structural engineers, who are permitted to plan and supervise certain classes of buildings and structures in common with licensed architects. Their former handicap, while not entirely eliminated, is largely removed. There also results another cleavage line between Engineers, as there are now Structural Engineers and others, the law recognizing only the first named. Perhaps, in time, separate licenses may be required for Sanitary Engineers, Electrical Engineers, Municipal Engineers, etc., etc., none of whom, however, could legally design the small structures appurtenant to his particular line of work.

Immediately upon its appointment, your Committee corresponded with from two to six members of the American Society of Civil Engineers in some 20 States, in an endeavor to ascertain whether efforts were being made to further Architectural licensing legislation; it found that such was the case in 8 States at least, but in each instance without success. It is apparent, therefore, that the Engineering Profession is in danger of the spreading of the discrimination which now exists in some States, and which in no small measure still remains in Illinois.

It seems to your Committee, therefore, that some organized effort should be made by the Engineering Profession to prevent further legislation discriminating against Engineers similar to the Architectural License laws in Colorado, Illinois, and other States; and it recommends that the other National Engineering Societies be asked to co-operate with the American Society of Civil Engineers with a view to taking such action as upon further investigation may appear desirable. Also, that the Joint Committee thus formed invite the co-operation of the American Institute of Architects in an endeavor to find some plan which may further the mutual esteem and co-operation of the two professions.

Pending the results of the steps just recommended, your Committee further recommends that this matter be referred to the Local Associations of this Society in all those States in which the Legislatures will convene this year, requesting that they take organized action in opposition to the enactment of any legislation for the licensing of the practice of Architecture, which would in any degree hamper or restrict the legitimate and proper practice of Engineers.

In States where there may be no Local Association, it is recommended that a State Committee be appointed to perform the same function.

Respectfully submitted,

C. F. Loweth,
Gardner S. Williams,
Daniel Bontecou,
Committee.

The Board of Direction, on January 17th, 1916, adopted the recommendations of this Report.

Pan-American Engineering Committee

The Board of Direction, on January 17th, 1916, authorized the appointment of representatives of this Society to act jointly with similar committees of the three other National Engineering Societies, for the purpose of promoting a closer political, social, scientific, commercial, and industrial association throughout the Americas, and to be known as the Pan-American Engineering Committee.

The following members have been appointed: Fred Lavis, Chairman; Chandler Davis, B. F. Cresson, Jr., P. W. Henry, and Edgar Marburg.

Committee on Legislative and Constitutional Matters

The report of the representatives of this Society appointed in connection with the Constitutional Convention of the State of New York was presented to the Board of Direction at its meeting of November 9th, 1915, and has been printed in the *Proceedings*.* At its meeting of January 17th, 1916, the Board authorized the appointment of a Committee of three to act with similar committees of other Engineering Societies as a Conference Committee for the consideration of all similar Legislative and Constitutional matters which may arise in this or other States. Messrs. Arthur S. Tuttle, Henry W. Hodge, and Alfred D. Flinn, the original representatives of the Society in this matter, were reappointed as such Committee.

* December, 1915, p. 74.

ANNOUNCEMENTS

The House of the Society is open from 9 A. M. to 10 P. M., every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

FUTURE MEETINGS

March 1st, 1916.—8.30 P. M.—A regular business meeting will be held, and two papers will be presented for discussion, as follows: "A Study of the Behavior of Rapid Sand Filters Subjected to the High-Velocity Method of Washing", by Joseph W. Ellms, M. Am. Soc. C. E., and John S. Gettrust, Esq.; and "The Effects of Straining Structural Steel and Wrought Iron," by Henry S. Prichard, M. Am. Soc. C. E.

These papers were printed in *Proceedings* for January, 1916.

March 15th, 1916.—8.30 P. M.—At this meeting a paper by George Henry Ellis, M. Am. Soc. C. E., entitled "The Flow of Water in Irrigation Channels", will be presented for discussion.

This paper is printed in this number of *Proceedings.*

April 5th, 1916.—8.30 P. M.—This will be a regular business meeting. A paper by A. C. Janni, M. Am. Soc. C. E., entitled "Method of Designing a Rectangular Reinforced Concrete Flat Slab, Each Side of Which Rests on Either Rigid or Yielding Supports", will be presented for discussion.

This paper is printed in this number of *Proceedings.*

ANNUAL CONVENTION

The Forty-eighth Annual Convention of the Society will be held at Pittsburgh, Pa., from June 27th to 30th, 1916, inclusive.

Arrangements for the Convention are in the hands of the following Local Committee:

George S. Davison, *Chairman,*

J. A. Atwood,	D. W. McNaugher,
R. A. Cummings,	Emil Swensson,
Richard Khuen,	E. B. Taylor,
Morris Knowles,	W. G. Wilkins,

Paul L. Wolfel.

SEARCHES IN THE LIBRARY

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

It sometimes happens that references are found which are not readily accessible to the person for whom the search is made. In that case the material may be reproduced by photography, and this can be done for members at the cost of the work to the Society, which is small. This method is particularly useful when there are drawings or figures in the text, which would be very expensive to reproduce by hand.

PAPERS AND DISCUSSIONS

Members and others who take part in the oral discussions of the papers presented are urged to revise their remarks promptly. Written communications from those who cannot attend the meetings should be sent in at the earliest possible date after the issue of a paper in *Proceedings.*

All papers accepted by the Publication Committee are classified by the Committee with respect to their availability for discussion at meetings.

Papers which, from their general nature, appear to be of a character suitable for oral discussion, will be published as heretofore in *Proceedings,* and set down for presentation to a future meeting of the Society, and on these, oral discussions, as well as written communications, will be solicited.

All papers which do not come under this heading, that is to say, those which from their mathematical or technical nature, in the opinion of the Committee, are not adapted to oral discussion, will not be scheduled for presentation to any meeting. Such papers will be published in *Proceedings* in the same manner as those which are to be presented at meetings, but written discussions only will be requested for subsequent publication in *Proceedings* and with the paper in the volumes of *Transactions.*

The Board of Direction has adopted rules for the preparation and presentation of papers, which will be found on page 429 of the August, 1913, *Proceedings.*

LOCAL ASSOCIATIONS OF MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

San Francisco Association

The San Francisco Association of Members of the American Society of Civil Engineers holds regular bi-monthly meetings, with banquet, and weekly informal luncheons. The former are held at 6 P. M., at the Palace Hotel, on the third Friday of February, April, June, August, October, and December, the last being the Annual Meeting of the Association.

Informal luncheons are held at 12.15 P. M., every Wednesday, and the place of meeting may be ascertained by communicating with the Secretary of the Association, E. T. Thurston, 713 Mechanics' Institute, 57 Post Street.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in San Francisco, and any such member will be gladly welcomed as a guest.

Colorado Association

The meetings of the Colorado Association of Members of the American Society of Civil Engineers (Denver, Colo.) are held on the second Saturday of each month, except July and August. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary, L. R. Hinman, 1400 West Colfax Ave., Denver, Colo. The meetings are usually preceded by an informal dinner. Members of the American Society of Civil Engineers will be welcomed at these meetings.

Weekly luncheons are held on Wednesdays, at 12.30 P. M., at Clarke's Restaurant, 1632 Champa Street.

Visiting members are urged to attend the meetings and luncheons.

(Abstract of Minutes of Meeting)

November 13th, 1915.—The meeting was called to order at the Denver Athletic Club; President John E. Field in the chair; L. R. Hinman, Secretary; and present, also, 19 members and 7 guests.

The minutes of the meeting of October 9th, 1915, were read and approved.

Mr. F. C. Steinhaur, Superintendent of Mountain Parks, City and County of Denver, addressed the meeting on "Construction of Automobile Highways in the Mountain Parks". The subject was generally discussed, and brief descriptions of the Estes Park-Grand Lake Highway and of the road to the summit of Pike's Peak, were given by Messrs. Fred C. Dreher and L. E. Bishop, respectively.

A vote of thanks was tendered Mr. Steinhaur for his address.

Adjourned.

Atlanta Association

The Atlanta Association of Members of the American Society of Civil Engineers was organized on March 14th, 1912. The Association holds its meetings at the University Club, Atlanta, Ga.

At the meeting of the Association on January 9th, 1915, the following officers were elected for the ensuing year: President, Park A.

Dallis; First Vice-President, B. M. Hall; Second Vice-President, P. H. Norcross; Secretary-Treasurer, T. B. Branch.

Baltimore Association

On May 6th, 1914, the Baltimore Association of Members of the American Society of Civil Engineers was organized, a Constitution adopted, and the following officers were elected: J. E. Greiner, President; Francis Lee Stuart, First Vice-President; L. H. Beach, Second Vice-President; Harry D. Williar, Jr., Secretary-Treasurer; and Messrs. H. D. Bush, B. T. Fendall, B. P. Harrison, Calvin W. Hendrick, Oscar F. Lackey, M. A. Long, and A. A. Thompson, Directors.

At its meeting of September 2d, 1914, the Board of Direction considered and approved the proposed Constitution of the Baltimore Association of Members of the American Society of Civil Engineers.

Cleveland Association

The proposed Constitution of the Cleveland Association of Members of the American Society of Civil Engineers was considered and approved by the Board of Direction of the Society on January 6th, 1915.

At the meeting of the Association on December 18th, 1915, the following officers were elected for the ensuing year: President, Robert Hoffmann; Vice-President, Wilbur J. Watson; and Secretary-Treasurer, George H. Tinker.

Louisiana Association

At the meeting of the Louisiana Association of Members of the American Society of Civil Engineers (New Orleans, La.), on April 14th, 1915, the following officers were elected for the ensuing year: J. F. Coleman, President; W. B. Gregory and A. M. Shaw, Vice-Presidents; Ole K. Olsen, Treasurer; and E. H. Coleman, Secretary.

Northwestern Association

The proposed Constitution of the Northwestern Association of Members of the American Society of Civil Engineers (St. Paul and Minneapolis, Minn.) was considered and approved by the Board of Direction of the Society on November 4th, 1914.

The officers of the Association are as follows: President, W. L. Darling; First Vice-President, George L. Wilson; Second Vice-President, L. W. Rundlett; Secretary, R. D. Thomas; and Treasurer, A. F. Meyer.

Philadelphia Association

The meetings of the Philadelphia Association of Members of the American Society of Civil Engineers are held at the Engineers' Club of Philadelphia, 1317 Spruce Street.

The officers of the Association are as follows: President, Edward B. Temple; Vice-Presidents, Edgar Marburg and John Sterling Deans; Directors, J. W. Ledoux, H. S. Smith, Henry H. Quimby, and George A. Zinn; Past-Presidents, George S. Webster and Richard L. Humphrey; Treasurer, S. M. Swaab; and Secretary, W. L. Stevenson.

(Abstract of Minutes of Meeting)

January 3d, 1916.—The meeting was called to order; President Edward B. Temple in the chair; W. L. Stevenson, Secretary; and present, also, John W. Ledoux, President of the Engineers' Club of Philadelphia, and about 270 members of the two organizations, the meeting having been held as a joint meeting of the Association and the Engineers' Club.

The following resolution was passed unanimously:

"The Philadelphia Association endorses Mr. Henry H. Quimby of Philadelphia for representative of the Fourth District of the Nominating Committee of the American Society of Civil Engineers."

President Temple addressed the meeting briefly relative to the signal honor shown the Engineering Profession and the Association by the appointment of Mr. George S. Webster as Director of the Department of Wharves, Docks, and Ferries, and of Mr. George E. Datesman as Director of the Department of Public Works, of Philadelphia.

An illustrated lecture on the "Electrification of the Pennsylvania Railroad Lines from Broad Street, Philadelphia, to Paoli, Pa.", was then given by Mr. George Gibbs.

A vote of thanks was tendered Mr. Gibbs.

Adjourned.

Portland, Ore., Association

At the Annual Meeting of the Association on September 28th, 1915, the following officers were elected for the ensuing year: President, J. P. Newell; First Vice-President, John T. Whistler; Second Vice-President, E. B. Thomson; Treasurer, Russell Chase; and Secretary, J. A. Currey.

St. Louis Association

The proposed Constitution of the St. Louis Association of Members of the American Society of Civil Engineers was considered and approved by the Board of Direction of the Society on October 7th, 1914.

The following officers have been elected: President, J. A. Ockerson; First Vice-President, Edward E. Wall; Second Vice-President, F. J. Jonah; Secretary-Treasurer, Gurdon G. Black. The meetings of the Association are held at the Engineers' Club Auditorium.

San Diego Association

The San Diego Association of Members of the American Society of Civil Engineers was organized on February 5th, 1915, and officers have been elected, as follows: President, George Butler; Vice-President, Willis J. Dean; and Secretary-Treasurer, J. R. Comly.

At its meeting of September 20th, 1915, the Board of Direction considered and approved the proposed Constitution of the San Diego Association of Members of the American Society of Civil Engineers.

Seattle Association

The Seattle Association of Members of the American Society of Civil Engineers was organized on June 30th, 1913. At its meeting of January 25th, 1915, the following officers were elected for the ensuing year: President, R. H. Ober; Vice-President, A. S. Downey; and Secretary-Treasurer, Carl H. Reeves.

Southern California Association

The Southern California Association of Members of the American Society of Civil Engineers (Los Angeles, Cal.) holds regular bimonthly meetings, with banquet, on the second Wednesday of February, April, June, August, October, and December, the last being the Annual Meeting of the Association.

Informal luncheons are held at 12.15 P. M. every Wednesday, and the place of meeting may be ascertained from the Secretary of the Association, W. K. Barnard, 701 Central Building, Los Angeles, Cal.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in Los Angeles, and any such member will be gladly welcomed as a guest at any of the meetings or luncheons.

Spokane Association

The proposed Constitution of the Spokane Association of Members of the American Society of Civil Engineers was considered and approved by the Board of Direction of the Society on March 4th, 1914. Ulysses B. Hough is President.

Texas Association

The proposed Constitution of the Texas Association of Members of the American Society of Civil Engineers was considered and approved by the Board of Direction of the Society on December 31st, 1913. The headquarters of the Association is Dallas, Tex. John B. Hawley is President.

MINUTES OF MEETINGS OF SPECIAL COMMITTEES TO REPORT UPON ENGINEERING SUBJECTS

Special Committee to Investigate Conditions of Employment of, and Compensation of, Civil Engineers

January 4th, 1916.—The meeting was held at the House of the Society. Present, Nelson P. Lewis (Chairman), John A. Bensel, S. L. F. Deyo, William V. Judson, and George W. Tillson (Secretary).

The Chairman made a statement regarding the work done in securing information since the previous circular letter had been sent out, and submitted a preliminary draft of a report, with diagrams, relative to that information. After discussion it was decided to prepare new diagrams, on a slightly different basis, and submit them with the report.

It was also decided that the report of the Committee, to be presented to the Annual Meeting, should state that nothing further of value could be obtained with respect to the compensation of civil engineers, and that the Committee had not attempted to procure information relative to the conditions of engineering employment, as it would be extremely difficult to secure reliable data on that subject; but, if the Society so directed, the Committee would undertake to obtain all possible information during the coming year.

Special Committee on Valuation of Public Utilities

December 27th, 28th, 29th, 30th, 31st, 1915, and January 1st, 1916.—Fifteen sessions were held at the Society House. Present, F. P. Stearns (Chairman), C. S. Churchill, W. G. Raymond, H. E. Riggs, J. P. Snow, W. J. Wilgus, and Leonard Metcalf (Secretary). The day sessions, in general, lasted from 9 A. M. to 6 P. M., and the night sessions from 8 to 10 P. M. Six of the seven members of the Committee were present at all the sessions, and the seventh member was present at five sessions.

Three and one-half days were devoted to the discussion of the revised draft of the chapter on "Reproduction Cost", previously outlined and modified in correspondence; two days were devoted to discussion of the chapter on "Depreciation"; and one-half day to the revised draft of the chapter on "Development Expense".

The revision of the various chapters, discussed in such a manner as to accord with the presentation of the subject agreed on in conference, was delegated to the different members of the Committee, with the understanding that a copy of the revised drafts would be sent to all members for further discussion and revision by correspondence.

The meeting was adjourned subject to the call of the Chairman—it being suggested that the next session be held during April, 1916.

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms, and at all meetings:

American Institute of Electrical Engineers, 33 West Thirty-ninth Street, New York City.

American Institute of Mining Engineers, 29 West Thirty-ninth Street, New York City.

American Society of Mechanical Engineers, 29 West Thirty-ninth Street, New York City.

Architekten-Verein zu Berlin, Wilhelmstrasse 92, Berlin W. 66. Germany.

Associação dos Engenheiros Civis Portuguezes, Lisbon, Portugal.

Australasian Institute of Mining Engineers, Melbourne, Victoria, Australia.

Boston Society of Civil Engineers, 715 Tremont Temple, Boston, Mass.

Brooklyn Engineers' Club, 117 Remsen Street, Brooklyn, N. Y.

Canadian Society of Civil Engineers, 176 Mansfield Street, Montreal, Que., Canada.

Civil Engineers' Society of St. Paul, St. Paul, Minn.

Cleveland Engineering Society, Chamber of Commerce Building, Cleveland, Ohio.

Cleveland Institute of Engineers, Middlesbrough, England.

Dansk Ingeniorforening, Amaliegade 38, Copenhagen, Denmark.

Detroit Engineering Society, 46 Grand River Avenue, West. Detroit, Mich.

Engineers and Architects Club of Louisville, 1412 Starks Building, Louisville, Ky.

Engineers' Club of Baltimore, 6 West Eager Street, Baltimore, Md.

Engineers' Club of Kansas City, E. B. Murray, Secretary, 920 Walnut Street, Kansas City, Mo.

Engineers' Club of Minneapolis, 17 South Sixth Street, Minneapolis, Minn.

Engineers' Club of Philadelphia, 1317 Spruce Street, Philadelphia, Pa.

Engineers' Club of St. Louis, 3817 Olive Street, St. Louis, Mo.

Engineers' Club of Toronto, 96 King Street, West, Toronto, Ont., Canada.

Engineers' Club of Trenton, Trent Theatre Building, 12 North Warren Street, Trenton, N. J.

Engineers' Society of Northeastern Pennsylvania, 415 Washington Avenue, Scranton, Pa.

Engineers' Society of Pennsylvania, 31 South Front Street, Harrisburg, Pa.

Engineers' Society of Western Pennsylvania, 2511 Oliver Building, Pittsburgh, Pa.

Institute of Marine Engineers, The Minories, Tower Hill, London, E., England.

Institution of Engineers of the River Plate, Calle 25 de Mayo 195, Buenos Aires, Argentine Republic.

Institution of Naval Architects, 5 Adelphi Terrace, London, W. C., England.

Junior Institution of Engineers, 39 Victoria Street, Westminster. S. W., London, England.

Koninklijk Instituut van Ingenieurs, The Hague, The Netherlands.

Louisiana Engineering Society, State Museum Building, Chartres and St. Ann Streets, New Orleans, La.

Memphis Engineers' Club, Memphis, Tenn.

Midland Institute of Mining, Civil and Mechanical Engineers, Sheffield, England.

Montana Society of Engineers, Butte, Mont.

North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne, England.

Oesterreichischer Ingenieur= und Architekten=Verein, Eschenbachgasse 9, Vienna, Austria.

Oregon Society of Civil Engineers, Portland, Ore.

Pacific Northwest Society of Engineers, 312 Central Building, Seattle, Wash.

Rochester Engineering Society, Rochester, N. Y.

Sachsischer Ingenieur= und Architekten=Verein, Dresden, Germany.

Sociedad Colombiana de Ingenieros, Bogota, Colombia.

Sociedad de Ingenieros del Peru, Lima, Peru.

Societe des Ingenieurs Civils de France, 19 rue Blanche, Paris, France.

Society of Engineers, 17 Victoria Street, Westminster, S. W., London, England.

Svenska Teknologforeningen, Brunkebergstorg 18, Stockholm, Sweden.

Tekniske Forening, Vestre Boulevard 18–1, Copenhagen, Denmark.

Western Society of Engineers, 1737 Monadnock Block, Chicago, Ill.

ACCESSIONS TO THE LIBRARY

(From January 4th, to February 1st, 1916)

DONATIONS*

RIVER DISCHARGE

Prepared for the Use of Engineers and Students. By John Clayton Hoyt and Nathan Clifford Grover, Members, Am. Soc. C. E. Third Edition, Revised and Enlarged. Cloth, 9 x 6 in., illus., 12 + 182 pp. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Limited, 1914. $2.00.

The application of water to power, irrigation, and other engineering works, as well as the methods of collecting and using data concerning the flow of streams, have been developed to such an extent that the work has come to be recognized, it is stated, as a branch of hydraulics to be included in regular courses of engineering schools, and as essential to the work of the practicing engineer. In this the third edition of their book, the authors include concise and clear descriptions of instruments and equipment for measuring flowing water, as well as their installation, methods of measuring the flow of natural and artificial channels, together with methods and procedure of analyzing and interpretating stream-flow data, conditions affecting the flow of water in streams, and the routine of the selection, establishment, and maintenance of gauging stations. Definitions of terms used in the work are given, as well as tables for facilitating the computation of various hydraulic problems, and lengthy theoretical and mathematical discussions have been avoided, it is said, in order to adapt the use of the book to the needs of hydraulic engineers, superintendents of irrigation, managers of power plants, engineering students, etc. The Chapter headings are: Introduction; Instruments and Equipment; Velocity-Area Stations; Weir Stations; Discussion and Use of Data; Conditious Affecting Stream Flow; Tables; Index.

LIVE-LOAD STRESSES IN RAILWAY BRIDGES

With Formulas and Tables. By George E. Beggs, Assoc. M. Am. Soc. C. E. Cloth, 9¼ x 5¾ in., illus., 4 + 123 pp. New York, John Wiley and Sons, Inc.; London, Chapman & Hall, Limited, 1916. $2.00.

In this volume, the author, it is stated, has treated stresses caused by moving concentrated loads by the combined use of influence lines and algebraic methods, the influence lines being connected with tables of moment sums and load sums in a new and practical manner. The preface states that the main feature of the text is contained in two equations which give an easy and exact solution of the maximum live-load stresses in any structure, the influence lines of which can be drawn. A second feature is stated to be the application of these equations to the simpler structures, such as girder bridges, pier reactions, etc., fully worked-out problems being included. The text is supplemented by a very complete set of useful tables. The Contents are: Influence Lines: Definitions and Use; Sum and Rate of Variation of Ordinate-Load Products Between Two Diverging Lines; Sum and Rate of Variation of Ordinate-Load Products for Any Influence Line; Girder Bridge Without Panels: General Formulas for Pier Reaction and Its Rate of Variation; Girder Bridge With Panels; Through Pratt Truss; Three-Hinged Arch: Equivalent Uniform Loads; Method of Calculating Table of Load Sums and Moment Sums for Any Standard Loading; Summary of Formulas; Tables.

POLE AND TOWER LINES FOR ELECTRIC POWER TRANSMISSION.

By R. D. Coombs, M. Am. Soc. C. E. Cloth, 9 x 6½ in., illus., 8 + 272 pp. New York and London, McGraw-Hill Book Company, Inc., 1916. $2.50.

The number and length of transmission and distribution lines have increased with the growth of the electric light and power industries until they have become, it is stated, pretentious systems, the relation of which to other industries and to the public must be considered. In this book the author, it is said, has considered the question from the viewpoint of the structural engineer by discussing and describing in detail the design and construction of modern transmission lines and their supports, including loading requirements, kinds of wires and cables, wooden, steel, and concrete poles and towers, foundations, protective coatings, cost estimates,

* Unless otherwise specified, books in this list have been donated by the publishers.

etc. He has also included in the subject-matter the Joint Report Specifications for Crossings and a General Specification for Lines. Purely electrical problems, such as voltage, size of wires, insulator design, etc., have been omitted, the author's idea, as stated in the preface, having been to develop a clearer perception of the application of the laws of mechanics to the subject discussed. The Contents are: Types of Construction; Loading; Wires and Cables; Design; Wooden Poles; Steel Poles and Towers; Special Structures; Concrete Poles; Foundations; Protective Coatings; Line Material; Erection and Costs; Protection; Specifications; Index.

REINFORCED CONCRETE CONSTRUCTION:

Volume III, Bridges and Culverts. Prepared in the Extension Division of the University of Wisconsin, by George A. Hool, Assisted by Frank C. Thiessen. (Engineering Educational Series.) Cloth, 9¼ x 6¼ in., illus., 22 + 688 pp. New York and London, McGraw-Hill Book Company, Inc., 1916. $5.00.

This volume, it is stated, was originally planned to treat of the various types of reinforced concrete structures not mentioned in Volumes I and II. On account of the numerous requests for material on the analysis and design of arch bridges, however, it has seemed advisable to devote this volume to bridges and culverts in an attempt to meet the needs of students who have requested a textbook which is neither too complex or abbreviated for the average engineer to understand. This has been accomplished, it is stated, by omitting intricate mathematical analysis involving Calculus, by avoiding mathematical sign language whenever possible, and by including complete methods of design of both symmetrical and unsymmetrical arches, not only of single span but of multiple spans with elastic piers. Two entirely different methods of arch analysis are given, it is stated, and in order to gain clearness, the subject-matter has been carefully arranged and numerous drawings and illustrations are included. The Contents are: Part I, Arch Bridge; Part II, Slab and Girder Bridges; Part III, Culverts; Part IV, Notes on Construction Plant, by A. W. Ransome; Part V, Notes on Estimating, by Leslie H. Allen; Part VI, The Artistic Design of Concrete Bridges, by William J. Titus; Part VII, The Construction in Detail of Several Types of Concrete Bridges, by Albert M. Wolf; Part VIII, European Concrete Bridges, by Philip Aylett aud P. J. Markmann; Appendix: General Notation Used in Part I; Index.

ENGINEERING AS A CAREER:

A Series of Papers by Eminent Engineers. Edited by F. H. Newell, M. Am. Soc. C. E., and C. E. Drayer. Cloth, 7½ x 5¼ in., 12 + 214 pp. New York, D. Van Nostrand Company, 1916. $1.00.

The aim, in this book, has been, it is stated, to present to young men, to teachers, and to parents or advisors, some of the facts concerning the Engineering Profession in general and of different branches of engineering in particular. Each chapter has been written by an experienced engineer or by an expert in some branch of engineering, and each, it is said, has endeavored to answer the question as to opportunities and requisites for success and causes of failure in the Engineering Profession. The Contents are: Introduction; The Engineer and His Profession, by A. J. Himes; Shall My Boy Become an Engineer? by Franklin De R. Furman; Mechanical Engineering, by Worcester R. Warner; Railway Engineering, by A. W. Johnston; Hydraulic Engineering, by Chester W. Larner; Metallurgical Engineering, by J. H. Herron; Electrical Engineering, by W. H. Abbott; Chemical Engineering, by M. C. Whitaker; Iron and Steel Making, by S. T. Wellman; Marine Engineering, by J. C. Workman; Sanitary Engineering, by R. Winthrop Pratt; Municipal Engineering, by Robert Hoffmann; Municipal Needs, by Rudolph Blankenburg; Bridge Engineering, by Frank C. Osborn; Architecture, by Benjamin S. Hubbell; Mining, by F. B. Richards; Opportunities for a Mining Engineer, by Henry S. Munroe; The Lure of Private Practice, by Ernest McCullough; Vocational Guidance, by James F. Barker; Scientific Manufacturing and Its Opportunities, by Waldemar Kaempffert; Incomes of Technically Trained Men, by David Edgar Rice; Technical Man in Business, by John Ritchie, Jr.

INDEXING AND FILING:

A Manual of Standard Practice. By E. R. Hudders. Cloth, 8 x 6 in., illus., 12 + 292 pp. New York, The Ronald Press Company, 1916.

This volume has been written, it is stated in the preface, with the idea of clearing up some of the obscure points encountered in the indexing and filing of records, such as are ordinarily found in commercial organizations, and of setting forth the basic principles necessary to the establishment of a manual of standard practice. Some of the chapters are applicable, it is stated, to the filing of professional, semi-professional, and institutional records, and concrete examples are included to illustrate the author's ideas. Descriptions of various kinds of filing equipments and supplies are also given. The Contents are: Terminology and Definitions; Indexes; Rules for Writing Indexes; Rules for Filing Index Cards; Filing of Papers; Direct Alphabetic Filing; Alphabetic-Numeric Filing; Numeric Filing; Geographic Filing; Subject Filing; Lost Papers; Transferring; Central Filing Department; Classing and Grouping of Records; Notation; Information and Data Files; Catalog and Pamphlet Filing; Purchase Records; Sales Records; Credit Records; Filing of Sales Invoices; Filing of Purchase Invoices; Check and Voucher Filing; Filing of Electrotypes and Cuts; Filing Equipment; Filing in Lawyers' Offices; Architectural Filing; Files of an Accountant; Index.

Gifts have also been received from the following:

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Harvard Univ. 1 bound vol.
Hawaii-Agricultural Exper. Station. 2 pam.
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Massachusetts-Wachusett Mountain State Reservation Comm. 2 pam.
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New York State-Public Service Comm., First Dist. 4 bound vol.
New York State-Public Service Comm., Second Dist. 6 pam.
New York-State Board of Tax Commrs. 1 bound vol.
New York-State Dept. of Health. 1 pam.
Newark, N. J.-City Plan Comm. 1 vol.
Ohio-Committee to Revise the Road Laws of the State. 1 pam.
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Panama Canal. 1 vol., maps.
Pennsylvania-Public Service Comm. 11 pam.
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U. S.-Dept. of the Interior. 13 pam.
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West Virginia, Univ. of. 1 pam.
Western Australia-Geol. Survey. 3 pam.
Western Australia-Govt. Rys. and Tramways. 1 pam.
Williams, Maurice. 1 bound vol.
Wisconsin-Geol. and Natural History Survey. 3 bound vol.

BY PURCHASE

A History of Travel in America, Showing the Developments of Travel and Transportation from the Crude Methods of the Canoe and the Dog-Sled to the Highly Organized Railway Systems of the Present, Together with a Narrative of the Human Experiences and Changing Social Conditions that Accompanied this Economic Conquest of the Continent. By Seymour Dunbar. 4 Vol. Indianapolis. 1915.

Painting by Immersion and by Compressed Air: A Practical Handbook. By Arthur Seymour Jennings. New York and London, 1915.

Conference of Building Inspectors and Building Commissioners of the United States and Dominion of Canada at the Hotel Astor, New York City, May 14th, 1915.*

The Rare Earth Industry, Including the Manufacture of Incandescent Mantles, Pyrophoric Alloys, and Electrical Glow Lamps. By Sydney J. Johnstone. Together with a Chapter on the Industry of Radioactive Substances, by Alexander S. Russell. New York, 1915.

Return as to Water Undertakings in England and Wales. Local Government Board. London, 1915.

The World Almanac and Encyclopedia, 1916. New York.

Forscherarbeiten auf dem Gebiete des Eisenbetons: Heft 25: Die Rammwirkung im Erdreich, Versuche auf neuer Grundlage. Von Karl Zimmermann. Berlin, 1915.

Forschungsarbeiten auf dem Gebiete des Ingenieurwesens. Herausgegeben vom Verein Deutscher Ingenieure. Hefte 174, 175, 176, 177, 178, 179. Berlin, 1915.

Brooklyn Daily Eagle Almanac, 1916: A Book of Information, General of the World and Special of New York City and Long Island. Brooklyn.

The Engineering Index Annual for 1915: Compiled from the Engineering Index Published Monthly in the *Engineering Magazine* During 1915. New York, 1915.

Lehrbuch der Eisenhüttenkunde: Verfast für den Unterricht, den Betrieb, und das entwerfen von Eisenhüttenanlagen. Von Bernhard Osann. Erster Band: Roheisenerzeugung. Leipzig, 1915.

The Science and Practice of Management. By A. Hamilton Church. New York, 1914.

An Introduction to the Theory of Value on the Lines of Menger, Wieser, and Böhm-Bawerk. By William Smart. New Edition. London, 1910.

SUMMARY OF ACCESSIONS

(From January 4th, to February 1st, 1916)

Donations (including 7 duplicates)	249
By purchase	19
Total	268

MEMBERSHIP

(From January 7th, to February 3d, 1916)

ADDITIONS

MEMBERS		Date of Membership.
BROWN, ELLIOT CHIPMAN. Pres., Elliot C. Brown Co., 70 East 45th St., New York City	Assoc. M. M.	Oct. 31, 1911 Jan. 18, 1916
CLOSSON, EDGAR STONE. Town Engr., 3 Claridge Court, Montclair, N. J.	Jun. Assoc. M. M.	Sept. 4, 1906 May 2, 1911 Jan. 18, 1916
DE LA MATER, STEPHEN TRUESDELL. Cons. Engr., 520 Marquette Bldg., Chicago, Ill.	Assoc. M. M.	Nov. 4, 1908 Jan. 18, 1916
DERR, HOMER MUNRO. State Engr., State Capitol, Pierre, S. Dak.	Assoc. M. M.	Jan. 4, 1910 Jan. 18, 1916
EDWARDS, LLEWELLYN NATHANIEL. Superv. Engr. of Bridges, Ry. and Bridge Section, Dept. of Works, P. O. Box 23, Toronto, Ont., Canada	Assoc. M. M.	Mar. 1, 1910 Jan. 18, 1916
FITCH, SQUIRE EARNEST. County Asst. Engr., Chautauqua County, New York State Highway Dept., 42 Academy St., Westfield, N. Y.	Assoc. M. M.	July 9, 1906 Jan. 18, 1916
GOWDY, ROY COTSWORTH. Chf. Engr., Fort Worth & Denver City Ry., 404 Denver-Record Bldg., Fort Worth, Tex.	Assoc. M. M.	Oct. 31, 1911 Jan. 18, 1916
HIDINGER, LEROY LEMAYNE. Vice-Pres. and Treas., Morgan Eng. Co., 610 Goodwyn Inst. Bldg., Memphis, Tenn.	Assoc. M. M.	Oct. 4, 1910 Jan. 18, 1916
JONES, FRED ATWOOD. Cons. Engr., 311 Sumpter Bldg., Dallas, Tex.		Dec. 6, 1915
MAYHEW, ALFRED BOARDMAN. Asst. Engr., Miami Conservancy Dist., Dayton, Ohio.	Assoc. M. M.	Nov. 8, 1909 Jan. 18, 1916
ODONI, VINCENT PHILLIP. Chf. Engr., Tucson Farms Co., P. O. Box 187, Tucson, Ariz.	Assoc. M. M.	April 4, 1911 Jan. 18, 1916
OSBORN, IRWIN SELDEN. Cons. Engr. (The Allen-Osborn Co.), 957 Rose Bldg., Cleveland, Ohio	Assoc. M. M.	Dec. 3, 1912 Jan. 18, 1916
SACKETT, ROBERT LEMUEL. Dean of Eng., Pennsylvania State Coll., State College, Pa.	Assoc. M. M.	Feb. 6, 1907 Jan. 18, 1916
SANBORN, MORTON FRANKLIN. Asst. San. Engr., New York State Dept. of Health, 30 Ten Eyck Ave., Albany, N. Y.	Assoc. M. M.	Mar. 1, 1910 Jan. 18, 1916
SAVAGE, JOHN LUCIAN. Designing Engr., A. J. Wiley, and the U. S. Reclamation Service, 611 Idaho Bldg., Boise, Idaho..	Assoc. M. M.	May 1, 1907 Jan. 18, 1916

MEMBERS (*Continued*)

		Date of Membership.
SHOEMAKER, HARRY IVES. Care, Manila R. R., Manila, Philippine Islands	Assoc. M.	May 4, 1909
	M.	Nov. 10, 1915

ASSOCIATE MEMBERS

BALDWIN, ERNEST WOOD. Supervisor, Pacific Terminals, The Panama Canal, Balboa, Canal Zone, Panama		Dec. 6, 1915
BARTHOLOMEW, HERBERT. Pedro Miguel, Canal Zone, Panama		Dec. 6, 1915
BAYLIS, ROSWELL SPENCER. Huntington, N. Y.		Dec. 6, 1915
BOWLUS, FRED DREXEL. Box 185, San Fernando, Cal.	Jun.	Sept. 3, 1913
	Assoc. M.	Dec. 6, 1915
COVERT, JOHN FRANCIS. Chf. Engr., Sweetwater Water Co. and The San Diego Land Corporation, 406 Owl Drug Bldg., San Diego, Cal.		Aug. 31, 1915
DAVIS, DANIEL ELIAS. Asst. Engr., Chester & Fleming, 1111 Union Bank Bldg., Pittsburgh, Pa.	Jun.	Feb. 28, 1911
	Assoc. M.	Dec. 6 1915
DOWNING, CARL E. Engr. in Chg., Belzoni Drainage Dist., P. O. Box 11, Belzoni, Miss.	Jun.	Oct. 1, 1913
	Assoc. M.	Dec. 6, 1915
ENGH, ARTHUR. Office Engr., C., B. & Q. R. R., 547 West Jackson Boulevard, Chicago, Ill.		Jan. 17, 1916
FAUDE, FREDERIC MORRIS. Asst. Mgr., Cuyamaca Water Co., 916 Eighth St., San Diego, Cal.		Dec. 6, 1915
FEILD, JULIAN CLARENCE. Cons. Engr., City of Denison, 105 Feild Bldg., Denison, Tex.		Jan. 17, 1916
GARNER, CHESTER ARTHUR. 507 North Lake St., Warsaw, Ind.		Nov. 3, 1915
HATCH, FLETCHER AMES. Chf. Engr., Santa Marta Div., United Fruit Co., Santa Marta, Colombia		Dec. 6, 1915
HOWES, BENJAMIN ALFRED. 70 Fifth Ave., New York City.		Jan. 17, 1916
MCCLINTOCK, HALLETT EDWARD. Draftsman and Asst. Engr., U. P. R. R., 1810 Manderson St., Omaha, Nebr.		Dec. 6, 1915
MERRIMAN, RICHARD MANSFIELD. Cons. Engr., Central Valley, N. Y.	Jun.	Jan. 3, 1907
	Assoc. M.	Jan. 17, 1916
PALEN, ARCHIBALD E. Highway Engr., U. S. Office of Public Roads, Care, Forest Service, Denver, Colo.		Jan. 17, 1916
PICKERSGILL, WILLIAM COPELAND. Designing Engr., Water Supply Board, 661 Westminster St., Providence, R. I.		Jan. 17, 1916
RICHARDS, NATHANIEL ATHERTON. Secy. and New York Mgr., Purdy & Henderson, 45 East 17th St., New York City		Nov. 3, 1915
ROCHE, ALFRED EMMET. City Engr., Troy, N. Y.		Jan. 17, 1916
SAMANS, WALTER. Asst. Engr. to Chf. Engr., B. & L. E. R. R., Greenville, Pa.		Nov. 3, 1915

ASSOCIATE MEMBERS (*Continued*)

		Date of Membership.
STRONG, *ARTHUR LEON. County Engr., Skagit County, Mt. Vernon, Wash.		Dec. 6, 1915
SWETT, EVERETT HAROLD. Junior Engr., U. S. Reclamation Service, Montrose, Colo.	Jun.	Oct. 1, 1907
	Assoc. M.	Dec. 6, 1915
WILDER, ALVIN DUMOND. Asst. Engr., Spring Val. Water Co., San Francisco (Res., 2448 Prospect Street, Berkeley), Cal.	Jun.	Oct. 6, 1908
	Assoc. M.	Dec. 6, 1915

JUNIORS

BROKER, ALBERT EDWARD. Asst. County Highway Commr. of Milwaukee County, 2120 Grand Ave., Apartment 8, Milwaukee, Wis.	Jan. 17, 1916
COTTON, WILLIAM OWEN. Idaho Falls, Idaho	Jan. 17, 1916
GARCIA, PEDRO. Asst. Engr., Peruvian Irrig. Service, P. O. Box No. 35, Lima, Peru	Dec. 6, 1915
RICHARDS, WALTER ALAN. Care, Hardaway Contr. Co., Whitney, N. C.	Dec. 6, 1915
RUETTGERS, ARTHUR. Camp 9, U. S. Reclamation Service, Power, Mont.	Dec. 6, 1915
UNDERWOOD, HARRISON AUBREY. Estimating and Erecting Engr., Christian Constr. Co., P. O. Box 343, Durham, N. C.	Jan. 17, 1916
VEATCH, FRANCIS MONTGOMERY. 505 Mound St., Atchison, Kans.	Jan. 6, 1915
WARFEL, ADAM COOPER. 208 North 53d St., Philadelphia, Pa.	Dec. 6, 1915

RESIGNATIONS

MEMBERS

	Date of Resignation.
HUSS, GEORGE MOREHOUSE	Jan. 17, 1916
OBREITER, JOSEPH WILLIAM	Jan. 26, 1916

ASSOCIATE MEMBERS

DAY, EDWARD BLISS	Jan. 17, 1916
DUNN, OSWALD THORPE	Jan. 17, 1916
FISCHER, GUILLERMO GUSTAVO	Dec. 31, 1915
KING, ROY STEVENSON	Jan. 17, 1916
MAHON, ROSS LE HUNT	Feb. 3, 1916
MALUKOFF, ALEXIS JOSEPH	Jan. 17, 1916
O'HARA, FRANCIS JOSEPH	Jan. 17, 1916
PLANT, FRANCIS BENJAMIN	Jan. 25, 1916
SANER, CURTIS CHARLES	Jan. 17, 1916
SHELMIRE, ROBERT WARREN	Dec. 31, 1915
WADDELL, FREDERICK CREELMAN	Dec. 31, 1915

JUNIORS	Date of Resignation.
BAINES, WILLIAM HENRY	Jan. 17, 1916
BRINKERHOFF, GEORGE LOCKWOOD	Dec. 31, 1915
CALKINS, CHARLES DOW	Jan. 25, 1916
COBURN, HORACE BUTTERFIELD, JR.	Jan. 17, 1916
CURTIS, HAROLD EDWIN	Jan. 25, 1916
FONT, MANUEL	Jan. 17, 1916
LEMCKE, KARL WOLFGANG	Jan. 17, 1916
LESTER, HOMER ALLAN	Jan. 17, 1916
PECK, JOHN CALVIN	Jan. 25, 1916
SEELEY, HENRY ARTHUR	Jan. 17, 1916
SHAW, GUY RAY	Dec. 31, 1915
SMITH, WALTER MICKLE, JR.	Dec. 31, 1915

DEATHS

CLARK, LUDLOW VICTOR. Elected Associate, October 4th, 1892; died December 28th, 1915.

FOLLETT, WILLIAM W. Elected Member, July 5th, 1893; died December 30th, 1915.

HUNT, LOREN EDWARD. Elected Associate Member, June 3d, 1903; died January 9th, 1916.

SCHNEIDER, CHARLES CONRAD. Elected Member, February 6th, 1884; Director, 1887, '98-1900; Vice-President, 1902-03; President, 1905; died January 8th, 1916.

TATUM, SLEDGE. Elected Member, January 4th, 1910; died January 18th, 1916.

WILKES, JAMES KNAPP. Elected Associate Member, June 3d, 1891; Member, April 3d, 1906; died January 9th, 1916.

WILLIAMS, DAVID. Elected Member, May 4, 1898; died November 27th, 1915.

Total Membership of the Society, February 3d, 1916, 7 893.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST

(January 4th, to February 1st, 1916)

NOTE.—*This list is published for the purpose of placing before the members of this Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS

In the subjoined list of articles, references are given by the number prefixed to each journal in this list:

(1) *Journal,* Assoc. Eng. Soc., St. Louis, Mo., 30c.
(2) *Proceedings,* Engrs. Club of Phila., Philadelphia, Pa.
(3) *Journal,* Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal,* Western Soc. of Engrs., Chicago, Ill., 50c.
(5) *Transactions,* Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly,* Columbia Univ., New York City, 50c.
(7) *Gesundheits Ingenieur,* München, Germany.
(8) *Stevens Institute Indicator,* Hoboken, N. J., 50c.
(9) *Engineering Magazine,* New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, 432 Fourth Ave., New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News,* New York City, 15c.
(14) *Engineering Record,* New York City, 10c.
(15) *Railway Age Gazette,* New York City, 15c.
(16) *Engineering and Mining Journal,* New York City, 15c.
(17) *Electric Railway Journal,* New York City, 10c.
(18) *Railway Review,* Chicago, Ill., 15c.
(19) *Scientific American Supplement,* New York City, 10c.
(20) *Iron Age,* New York City, 20c.
(21) *Railway Engineer,* London, England, 1s. 2d.
(22) *Iron and Coal Trades Review,* London, England, 6d.
(23) *Railway Gazette,* London, England, 6d.
(24) *American Gas Light Journal,* New York City, 10c.
(25) *Railway Mechanical Engineer,* New York City, 20c.
(26) *Electrical Review,* London, England, 4d.
(27) *Electrical World,* New York City, 10c.
(28) *Journal,* New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal,* Royal Society of Arts, London, England, 6d.
(30) *Annales des Travaux Publics de Belgique,* Brussels, Belgium, 4 fr.
(31) *Annales* de l'Assoc. des Ing. Sortis des Ecoles Spéciales de Gand, Brussels, Belgium, 4 fr.
(32) *Mémoires et Compte Rendu des Travaux,* Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil,* Paris, France, 1 fr.
(34) *Portefeuille Economiques des Machines,* Paris, France.
(35) *Nouvelles Annales de la Construction,* Paris, France.
(36) *Cornell Civil Engineer,* Ithaca, N. Y.
(37) *Revue de Mécanique,* Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways,* Paris, France.
(39) *Technisches Gemeindeblatt,* Berlin, Germany, 0, 70m.
(40) *Zentralblatt der Bauverwaltung,* Berlin, Germany, 60 pfg.
(41) *Electrotechnische Zeitschrift,* Berlin, Germany.
(42) *Proceedings,* Am. Inst. Elec. Engrs., New York City, $1.
(43) *Annales des Ponts et Chaussées,* Paris, France.
(44) *Journal,* Military Service Institution, Governors Island, New York Harbor, 50c.
(45) *Coal Age,* New York City, 10c.
(46) *Scientific American,* New York City, 15c.
(47) *Mechanical Engineer,* Manchester, England, 3d.
(48) *Zeitschrift,* Verein Deutscher Ingenieure, Berlin, Germany, 1, 60m.
(49) *Zeitschrift für Bauwesen,* Berlin, Germany.
(50) *Stahl und Eisen,* Düsseldorf, Germany.
(51) *Deutsche Bauzeitung,* Berlin, Germany.
(52) *Rigasche Industrie-Zeitung,* Riga, Russia, 25 kop.
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(56) *Transactions,* Am. Inst. Min. Engrs., New York City, $6.

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The Broader Duties of the Engineer. J. C. Ralston. (Paper read before the Oregon Soc. of Engrs.) (1) Dec., 1915.
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Cost-Keeping and Efficiency in Works of the Engineer Department.* Stuart C. Godfrey. (100) Jan.
The Development of a Dynamic Theory of Soil Fertility. Frank K. Cameron. (3) Jan.
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The Hardwood Distillation Industry. G. W. Katzenstein. (From the *Journal of Industrial and Chemical Engineering.*) (19) Jan. 1.
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Pick Rational Plant Units for Depreciation Accounting. Robert G. Klotz. (13) Jan. 6.
Jersey Combination Shop's Efficient Service.* (101) Jan. 7.

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Field Lithography Permits Rapid Production of Maps. D. A. Tomlinson. (14) Jan. 8.
Regulation of Public Utilities. C. A. Prouty. (Paper read before the Pan-American Scientific Congress.) (15) Jan. 14.
Co-operation of Societies Needed to Secure Equitable Specifications and Contracts. (14) Jan. 15.
The Pine Needle Oil Industry.* Samuel J. Record. (46) Jan. 22.
Report of the Committee on Nomenclature and Standards of the Illuminating Engineering Society. (24) Jan. 24.
Das Grundgesetz des Wärmeüberganges. Wilhelm Nusselt. (7) Serial beginning Oct. 16, 1915.
Das Benzin, seine Gewinnung, Beschaffenheit und Lagerung. H. Strache. (53) Serial beginning Dec. 24, 1915.

Municipal.

Concrete Roads of Wayne County, Michigan. (60) Dec., 1915.
Durability of Creosoted Block Pavements Increased by Modern Methods of Treatment.* Frank W. Cherrington. (60) Dec., 1915.
The Administration of European Cities. Julius Pitzman. (Paper read before the Engrs. Club of St. Louis.) (1) Dec., 1915.
Arterial Roads in Greater London. W. R. Davidge. (Paper read before the Town Planning Inst.) (104) Dec. 17, 1915.
Bituminous Resurfacing of Old Roads.* J. C. Travilla. (Paper read before the Inter. Road Congress.) (60) Jan.
Sanitary Provisions Being Inserted in Scottish Town Planning Schemes. Wm. Ross Young. (114) Jan.
Pelham Manor Concrete Road.* Charles A. Mullen. (60) Jan.
Motorization Effects Big Savings in New York Fire Department.* (60) Jan.
An Example of Modern Practice in Road Improvement, Fayette County, Kentucky.* (86) Jan. 5.
Progress in Asphalt Refining; With Notes on Mexican Asphaltic Crudes. Leroy M. Law. (Abstract from paper read before the Worcester Convention.) (96) Jan. 6.
Canadian Highway Development; With Notes Regarding Ontario's System. William A. McLean. (Abstract from paper read before the Inter. Road Congress.) (96) Jan. 6.
Morgan Park, A Beautiful Steel-Mill Town.* (20) Jan. 6.
Reducing Hillside Street Grade from 29 to 16 Per Cent.* (13) Jan. 6.
Dual Type of Brick Paving Aids Traffic on Grades.* (14) Jan. 8.
Proportioning of Concrete for Road Work, Suggestions for Improvement and Obstacles in the Way. W. W. Crosby. (86) Jan. 12.
Economic Highway Construction; An Analysis of Roadway Sections.* F. W. Harris. (86) Jan. 12.
Laying a Monolithic Brick Pavement in Car Track.* (13) Jan. 13.
Examination of Bituminous Road Materials. Prevost Hubbard and Charles S. Reeve. (Abstract from *Bulletin*, U. S. Office of Public Roads.) (96) Jan. 13.
Paving Maintenance Should Include Cost of Cleaning.* (14) Jan. 15.
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A Study of Cushions for Pavements of the Block Type. Maurice B. Greenough. (Paper read before the Am. Assoc. for the Advancement of Science.) (86) Jan. 19.
Pitch Fillers for Block Pavements.* John S. Crandell. (96) Jan. 20.
Proper Oil for Creosoting Wood Blocks for Paving. P. C. Reilly. (18) Jan. 22.
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Some Radical Changes in Brick-Pavement Construction.* P. C. McArdle. (13) Jan. 27.
Elevation of Low-Level Streets on Pittsburgh River Front.* Charles M. Reppert. (13) Jan. 27.
Das sanitäre Grün.* Martin Wagner. (39) Serial beginning Sept. 18, 1915.
Raddruck und Felgenbreite. Kayser. (40) Sept. 22, 1915.
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Alt- und Neu-Hamburg.* Martin Mayer. (40) Oct. 20, 1915.
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A 5 000 Volt, Direct Current Electric Railway.* Irving B. Smith. (19) Dec. 11, 1915.

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Converted Tank Engine, Great Central Railway.* **(23)** Dec. 31, 1915.
The Jarrow Collision.* **(23)** Dec. 31, 1915.
The Canadian Pacific Railway System. **(23)** Dec. 31, 1915.
Electric Traction on the Giovi Line.* **(73)** Serial beginning Dec. 31, 1915.
The Railway Situation from Different Viewpoints. Julius Kruttschnitt and others. **(15)** Dec. 31, 1915.
Cars and Locomotives Ordered and Built in 1915. **(15)** Dec. 31, 1915.
Mileage of American Railroads Block Signaled. **(15)** Dec. 31, 1915.
The Upkeep of Railway Wagons. **(12)** Dec. 31, 1915.
Comparative Locomotive Shop Ratios. Henry Gardner. **(25)** Jan.
The Magnolia Cut-Off on the Baltimore & Ohio Railroad.* **(87)** Jan.
Steel End Box Cars for the Santa Fe.* **(25)** Jan.; **(15)** Jan. 14.
Smoke and Electrification in Chicago. (Abstract of Report of Assoc. of Commerce.) **(25)** Jan.
The Causes of Shocks in Long Freight Trains. H. C. Priebe. (Abstract of paper read before the Car Foremen's Assoc.) **(25)** Jan.
Two Powerful 4-6-2 Locomotives.* **(25)** Jan.
The Life of a Steel Freight Car. Samuel Lynn. (Abstract of paper read before the Ry. Club of Pittsburgh.) **(25)** Jan.; **(15)** Jan. 7; **(18)** Jan. 15.
Widening of Gauge on Curves. Roger Atkinson. **(87)** Jan.
Nicholson Tunnel on the Delaware, Lackawanna & Western.* **(87)** Jan.
Anti-Collision Railway Carriages.* **(21)** Jan.
Methods and Value of Grade Separation at Crossings.* **(87)** Jan.
Electrification on the Pennsylvania Railroad.* **(87)** Jan.
The Chief Cause of Rail Creeping. Joe Rodman. **(87)** Jan.
Up-Grade Signals on the Delaware, Lackawanna & Western.* **(87)** Jan.
Formation and Prevention of Pockets and Soft Places. C. A. Davis. **(87)** Jan.
The Use of Brick for Station Platforms.* Edwin G. Zorn. **(18)** Jan. 1; **(76)** Jan. 4.
Considerations in Railway Power Distribution. F. H. Shepard. **(17)** Jan. 1.
Some Aspects of Heavy Electric Traction. E. H. McHenry. **(17)** Jan. 1.
Opportunities for Electrification. A. H. Armstrong. **(17)** Jan. 1.
Tentative Design for Overhead Contact System in the Electrification of Chicago Railway Terminals.* **(18)** Serial beginning Jan. 1.
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Improvements at Pawtucket and Central Falls.* **(15)** Jan. 7.
The Cleaning of Locomotive Boilers.* E. J. H. South. (Paper read before the Inst. of Locomotive Engrs.) **(23)** Jan. 7.
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Some Problems and Principles of Government Regulation of Railroads. Emory R. Johnson. (Paper read before the Pan-American Scientific Congress.) **(15)** Jan. 7.
The Largest British Built Locomotive.* **(22)** Jan. 7.
New Alternating Current Signal Installation on the Grand Trunk.* **(15)** Jan. 7.
No Attempt Yet to Fix Prices in Federal Valuation. **(14)** Jan. 8.
The Economics of Railway Signalling.* A. G. Shaver. **(18)** Jan. 8.
Superheaters and Oil Fuel for Indian Locomotives. H. Raynar Wilson. **(18)** Jan. 8.
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Tunnel Lining by Compressed Air Mixing and Placing.* **(86)** Jan. 12.
First All-Rail Through Route Across New York City.* **(13)** Jan. 13.
New Pittsburgh North Side Freight Station of the Pennsylvania Railroad.* Hartley M. Phelps. **(23)** Jan. 14.
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The Lately Revised Standard Code. Harry W. Forman. **(15)** Jan. 14.
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The Railway Traffic of the Chicago Terminal. **(15)** Jan. 14.
Sheet Piling a Remedy for Soft Spots in Wet Cuts.* E. L. Sinclair. **(14)** Jan. 15.
New Freight Terminal of the Lehigh Valley R. R. at Buffalo, N. Y.* **(18)** Jan. 15.

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Conditions on the Railways of Mexico.* (From the *New York Sun.*) (18) Jan. 15.
Admits that Market Value will not Reproduce Land. (14) Jan. 15.
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Woods Suitable for Cross-Ties. R. Van Metre. (Paper read before the Am. Wood Preservers Assoc.) (96) Jan. 20.
Possibilities of Steam Railroad Electrification. William Arthur. (Abstract of paper read before the New York Univ.) (15) Jan. 21.
Southern Railway High Capacity Dynamometer Cars.* (15) Jan. 21.
A Disastrous Collision with an Unusual Cause.* (15) Jan. 21.
The Permanent Track Organization on the Long Island. G. P. Williams. (15) Jan. 21.
Keeping a Railroad Line Open During Snow Storms. Coleman King and W. G. Dungan. (15) Jan. 21.
Some Suggestions for the Improvement of the Railroad Situation. W. J. Moroney. (15) Jan. 21.
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The Commission on Valuation for Rate-Making Purpose. Charles C. James. (From the *Journal of Accountancy.*) (15) Jan. 28.
Hand Signals for Crossing Watchmen.* (15) Jan. 28.
Reinforced Concrete Train Shed of Unit Construction.* (15) Jan. 28.
Belt Conveyors a Success in Pneumatic Tunnel Construction at Boston.* (14) Jan. 29.
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Berechnung von zweimittigen Korbbogen.* W. Strippgen. (102) Aug. 1, 1915.
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Zweiachsiger Rettungswagen der österreichischen Staatsbahnen.* G. Garlik Ritter von Osoppo. (102) Aug. 15, 1915.
Berechnung der kürzesten Fahrzeiten von Eisenbahnzügen.* E. Rosseck. (102) Serial beginning Sept. 1, 1915.
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Berechnung von zweimittigen Korbbogen mit Zwischengerade.* W. Strippgeu. (102) Sept. 15, 1915.
Einflusslinien zur Berechnung der Eisenbahnschienen.* Loewe. (102) Oct. 1, 1915.
Neue Anlage zum Warmauswaschen und zur Gewinnung warmen Wassers in Lokomotivschuppen. v. Glinski. (102) Oct. 15, 1915.
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Die neue Verordnung betr. Eisenbetonbauten der Aufsicht des Bundes unterstellten Transport-Anstalten, vom 26 November, 1915. Fritz Hübner. (107) Serial beginning Jan. 1.

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Titanium-Treated Rails in Boston.* (17) Jan. 1.
Line Crews Maintain T. H., I. & E. Light Signals.* A. Schlesinger. (17) Jan. 1.
New Electric Railway Track Built in 1915. (17) Jan. 1.
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Eliminated Stops in City Service. B. F. Wood, Paul E. Wilson, Elmer E. Strong, and J. V. Sullivan. (17) Jan. 1.
One-Man Cars Becoming Popular.* (17) Jan. 1.
Concrete Filler for Reinforcing Hollow Steel Poles.* (27) Jan. 1.
Fare Collection Revolutionized at Boston.* M. C. Brush. (Paper read before the Am. Elec. Ry. Assoc.) (17) Jan. 8.
Estimating Cost of Track Construction on a Unit-Time Basis.* Carl H. Fuller, Assoc. M. Am. Soc. C. E. (17) Jan. 8.
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The Development of the Automatic Car Curtain.* W. H. Forsyth. (17) Jan. 15.
Track Rehabilitation in Springfield, Ohio.* C. G. Keen. (17) Jan. 15.
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The Return Feeder System of the Interborough.* I. W. Gross. (17) Jan. 22.
Cars of High Seating Capacity for Hazleton.* (17) Jan. 22.
Load Dispatching at East St. Louis.* Harold W. Clapp. (17) Jan. 22.
Der Bau von Untergrundbahnen in Berlin.* Guntram Mahir. (39) Aug. 5, 1915.
Die Hochbahn in Hamburg.* G. Schimpff. (102) Serial beginning Sept. 1, 1915.

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Mechanical Ventilation.* James Keith. (Paper read before the Inst. of Marine Engrs.) (47) Nov. 26, 1915.
Treatment of Sewage with Electricity and Lime. (60) Dec., 1915.
Sanitary Improvement of a Large Watershed.* George G. Honness. (28) Dec., 1915.
Ozone for Ventilation.* (105) Dec. 15, 1915.
The Character and Extent of Atmospheric Pollution in English and Scotch Towns. John B. C. Kershaw. (105) Dec. 15, 1915.
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Kimberley City Sanitary System. James Dunn. (Report to the Town Council.) (104) Dec. 24, 1915.
The Activated Sludge Experiments at Salford. W. H. Duckworth. (Paper read before the Assoc. of Managers of Sewage Disposal Works.) (12) Dec. 31, 1915; (104) Dec. 24, 1915.
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Centrifugal Fans for Air Transmission.* Charles L. Hubbard. (101) Dec. 31, 1915.
Disposal of Suspended Matter in Sewage. Rudolph Hering. (Paper read before the Inter. Eng. Congress.) (104) Dec. 31, 1915.
Gasoline-Electric Tractors in New York Street Cleaning Service.* (60) Jan.
The Heat Insulating Properties of Commercial Steam Pipe Coverings.* L. B. McMillan. (55) Jan.
Handling a Peculiar Drainage Situation.* Albert Marple. (87) Jan.
Admission of Liquid Trade Waste Into Public Sewers. Reginald Brown. (114) Jan.
The Activated Sludge Method of Sewage Treatment. Edward Bartow. (60) Jan.
Comparative Rainfall Records Used in Designing Sewers and Drains.* (60) Jan.
The Street Cleaning Problem.* Gus H. Hanna. (Paper read before the Inter. Road Congress.) (60) Jan.; (86) Jan. 5.
Building a Six-Foot Segmental Sewer.* Benjamin Wilk. (76) Jan. 4.
A Notable Application of Electrically Driven Machinery in Sewer Construction at Salt Lake City, Utah.* Bayard W. Mendenhall. (86) Jan. 5.
Eight Years of Imhoff Tank Design and Operation.* Karl Imhoff. (13) Serial beginning Jan. 6.
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Central Station Heating System at Tuskegee.* (101) Jan. 7.
Municipal Swimming Pool Has Unique Features.* (101) Jan. 7.
Furnace Heating System in Rochester House.* Harold L. Alt. (101) Jan. 7.
Mammoth Screw Pumps of New Design Develop High Efficiencies for Low Lifts.* (14) Jan. 8.
Privately Financed Sewer System for Small Town Produces $2 000 Yearly Revenue. Henry W. Taylor. (14) Jan. 8.
What the Wood-Pump Test Means to New Orleans. George G. Earl. (13) Jan. 13.
Testing the 12-Ft. Wood-Nordberg Pump. W. H. P. Creighton. (13) Jan. 13.
Rideau River Intercepting Sewer.* L. McLaren Hunter. (96) Jan. 13.
Modern Wash Houses for Miners.* John A. Garcia. (45) Jan. 15.
Economic Desirability of Expert Operation and Maintenance of Drainage Pumping Plants. G. M. Woodward. (Abstract from *Bulletin 304*, Office of Public Roads and Rural Eng.) (86) Serial beginning Jan. 19.
Method of Keeping a Graphic Cost-Progress Record on Sewer Construction.* W. A. Bennett. (86) Jan. 19.
Data on Straddle Ditch Excavators in Drainage Work. D. L. Yarnell. (Abstract from *Bulletin 300*, Office of Public Roads and Rural Eng.) (86) Serial beginning Jan. 19.

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The Electrically Heated High School at Burley, Idaho.* F. E. Ware. (27) Jan. 22.
Gas Fired Steam Radiators for Heating Apartment Houses, a Successful Installation.* H. Thurston Owens. (24) Jan. 24.
British and American Patents on Activated Sludge. (13) Jan. 27.
Main Garrison Creek Storm Overflow Sewer and Extensions, Toronto. R. T. G. Jack. (96) Jan. 27.
Hydraulic Ejectors for Grit Removal Merit Trial in Sewer Maintenance.* John H. Gregory. (14) Jan. 29.
Installation de Filtration d'Eau à la Piscine Municipale Ledru-Rollin à Paris.* J. De Just. (33) Jan. 8.
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Die Kläranlage des Liller Schlachthofs.* P. Keim. (7) July 31, 1915.
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Betrachtungen über Druckrohrleitungen städtischer Entwässerungsanlagen.* Johannes von Hanffstengel. (7) Serial beginning Oct. 2, 1915.
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Ein Prozess wegen Vorfluterverunreinigung durch eine städtische Kläranlage. P. Rohland. (39) Oct. 20, 1915.
Abfallverwertung in der Tonindustrie. Max Roesler. (80) Oct. 21, 1915.
Die Magnetische Hand.* G. Klingenberg. (41) Dec. 16, 1915; (48) Dec. 15, 1915.

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The William Hall Walker Gymnasium.* (8) Oct., 1915.
Paint and Dye Testing. Wm. Roy Mott. (Paper read before the Am. Electrochemical Soc.) (19) Nov. 27, 1915.
Improving Concrete by the Use of Hydrated Lime. (60) Dec., 1915.
Fire Prevention. Charles E. Meek. (Paper read before the Pennsylvania Industrial and Public Welfare and Eng. Conference.) (98) Dec., 1915.
The Relative Corrodibilities of Iron and Steel. J. Newton Friend. (Paper read before the Faraday Soc.) (47) Dec. 17, 1915.
Results of Some Tests to Determine the Load Distributions Through Reinforced Concrete Slabs.* (86) Dec. 29, 1915.
Humidity-Control Process for the Drying of Lumber.* W. H. Lewis. (23) Dec. 31, 1915.
Discussion of Some Special Methods of Reinforced Concrete Design. J. R. Worcester, H. B. Andrews and M. J. Lorente. (109) Jan.
The Light-Reflecting Values of White and Colored Paints. Henry A. Gardner. (3) Jan.
Graphical Treatment of Elastic Ribs.* C. S. Whitney. (36) Jan.
Protective Coatings for Metals. H. B. C. Allison. (From the *General Electric Review.*) (19) Jan. 1.
Rigid Tests for Fire Brick and Fire Clay.* J. F. Mowat. (76) Jan. 4.
Design of a Million-Bushel Public Grain Elevator at New Orleans, La.* (86) Jan. 5.
Concrete Plant and Methods Used in Constructing Hotel Traymore, Atlantic City, N. J.* (86) Jan. 5.
Overdriven Piles and Poor Subaqueous Concrete.* R. W. Stewart. (13) Jan. 6.
Cleaning Hollow Piles with a 10-In. Orangepeel.* G. L. Knight. (13) Jan. 6.

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New Features in Concrete Spouting Plant.* (13) Jan. 6.
Reinforced Concrete T-Beams.* E. G. W. Montgomery. (104) Jan. 7.
Steel Frame of Printing Crafts Building Designed to Prevent Vibration.* (14) Jan. 8.
Requirements for Acceptance of Concrete Aggregates Based upon Standard Tests.* (14) Jan. 8.
Reinforced Concrete Combined with Timber for Coal Pockets and Trestle.* Charles F. Dingman. (14) Jan. 8.
High and Low Sulphur in Basic Steel.* J. S. Unger. (Paper read before the Soc. of Automobile Engrs.) (20) Jan. 13.
Some Notes on Reinforced Concrete.* R. M. Kearns. (Paper read before the Surveyors Institution.) (104) Jan. 14.
Ancient Lights. A. E. Porte. (Paper read before the Eng. and Scientific Assoc. of Ireland.) (104) Jan. 14.
Unique Helical Stairway is within Center Well.* Frank Reed. (14) Jan. 15.
Test Comparing Steam and Drop Hammer Pile Formulas. (13) Jan. 16.
The House of Happiness.* Louine Worden. (76) Jan. 18.
Some Data on the Operating Cost of Office Buildings. George W. Martin. (86) Jan. 19.
Experiments on the Distribution of Vertical Pressure Through Sand.* Melvin L. Enger. (86) Jan. 19; (18) Jan. 22.
The Corrosion of High Chromium Steels. Robert Hadfield. (Paper read before the Faraday Soc.) (20) Jan. 20.
Concrete Stadium a Part of a High School Building.* (13) Jan. 20.
Concrete Corrals Withstand Mule Heels.* (14) Jan. 22.
Butt Treatment of Piles and Poles Effective. (14) Jan. 22.
Arch-Truss Roof for Drill Hall.* (13) Jan. 27.
Factors Affecting the Life of Concrete Structures. Bertram Blount. (Paper read before the Inter. Eng. Congress.) (96) Jan. 27.
Greenheart, used in Panama Canal, is a Timber with Exceptional Qualities. A. K. Armstrong. (14) Serial beginning Jan. 29.
Large Volume of Concrete Handled in Small Batches at Halifax Ocean Terminals.* (14) Jan. 29.
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Slag Concrete Stronger than Broken Stone. (14) Jan. 29.
Tables Facilitate Accuracy in Timber Beam Design. R. C. Hardman. (14) Jan. 29.
Four Street Shaft Plants to Handle 300 000 Yards of Excavation in Twelve Months.* (14) Jan. 29.
La Thermo-Electricité des Aciers Spéciaux.* Eugène L. Dupuy et Albert M. Portevin. (93) Aug., 1915.
Die Rammwirkung im Erdreich, Versuche auf neuer Grundlage.* Karl Zimmermann. (79) Vol. 25.
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* Illustrated.

PAPERS AND DISCUSSIONS

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Vol. XLII. FEBRUARY, 1916. No. 2.

AMERICAN SOCIETY OF CIVIL ENGINEERS

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PAPERS AND DISCUSSIONS

THE FLOW OF WATER IN IRRIGATION CHANNELS

By George Henry Ellis, Assoc. M. Am. Soc. C. E.

To be Presented March 15th, 1916.

Synopsis.

This paper presents a study of some data recently published as *Bulletin No. 194* of the United States Department of Agriculture. An exponential formula is deduced for the flow of water, $V = C\,R^{0.69}\,S^{0.5}$, in which the coefficient, C, varies from about 40 to 140, depending on the roughness of the channel. For general conditions, the following formulas are submitted:

For concrete channels...... $V = 105\,R^{0.69}\,S^{0.5}$.

For wooden channels....... $V = 100\,R^{0.69}\,S^{0.5}$.

For earth canals........... $V = 60\,R^{0.69}\,S^{0.5}$.

Incidentally, this paper shows the need of care in the selection of a value for the coefficient of roughness. For example, Experiment No. 4, Table 1, was conducted under conditions which gave a value of n, in Kutter's formula, equal to 0.0108. Entering Fig. 3 with this value of n, it is observed that from 140 to 145 would have been a better value for C (in the writer's formula) than the 123.7 which was used. With $C = 140$ we get a velocity of 20.1.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

The data on which this paper is based were taken on ditches with hydraulic radii up to about 4.0 and slopes ranging from about 0.01 to 0.0001.

Table 3 gives the 0.69th powers of radii.

Considerable interest has been manifested in this subject during recent years, and experimental work has been done by the U. S. Reclamation Service, the various State Experiment Stations, the U. S. Office of Experiment Stations, and by individuals. The Office of Experiment Stations has collected and published as a bulletin all recent available data on this subject.* This paper uses the tabulated data on pages 19 to 27 of that bulletin for the purpose of finding a simpler formula for the flow of water.

Different investigators use different methods for determining the hydraulic elements of a ditch. Those used by the Office of Experiment Stations are described in detail in the bulletin mentioned. Briefly, a stretch of canal was chosen, about 1 000 ft. long, and with conditions as nearly uniform as possible throughout its length. Bench-marks were set at each end, and several cross-sections were taken in order to determine the areas and perimeters. The discharge was measured generally with a current meter at the center of the reach chosen, and referred to readings of the water surface on the bench-marks at each end.

The claim has been made that water can be measured to within 1% with a current meter. The writer believes that results within 2 or 3% can be obtained with this instrument under favorable conditions, but doubts whether dependence can be placed on it within less than about 5% for all sorts of conditions. Hoyt and Grover give tables† which seem to indicate that even this is optimistic. In setting the bench-marks for the determination of the slope, there is another chance for error. Assuming an allowable error (in feet) of 0.017 $\sqrt{\text{distance, in miles}}$, gives an error of 0.0074 in 1 000 ft. A slope of 0.0001—which is about as flat as any canal is built—has a fall of 0.1 ft. in that distance. The probable error in levels would then be 7.4% on a ditch having a slope of 0.0001.

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* *Bulletin No. 194*, U. S. Department of Agriculture, May 10th, 1915.

† "River Discharge", pp. 111 and 112.

Water runs in a canal by merely sliding down hill—a process so simple that to make experiments and write papers on it seems almost absurd—and yet, because of the many things affecting friction, not very much is known about the flow of water, and this little paper will be worth while if it does no more than call attention to recently published data and start a discussion which may lead to the adoption of a more simple formula than that now in use.

In 1775 Chezy proposed his well-known formula for the flow of water, $V = C\sqrt{R\,S}$.

In 1869 Ganguillet and Kutter enlarged this by their empirical value of C:

$$V = \left\{ \frac{\dfrac{1.811}{n} + 41.6 + \dfrac{0.00281}{s}}{1 + \left[41.6 + \dfrac{0.00281}{s}\right] \dfrac{n}{\sqrt{R}}} \right\} \sqrt{R\,S}.$$

In 1897 Bazin attempted to shorten this by proposing a simpler value of C:

$$V = \frac{157.6}{1 + \dfrac{\gamma}{\sqrt{R}}} \sqrt{R\,S}.*$$

Engineers, however, had become so accustomed to thinking in terms of n, that they were loth to change. In 1911 Johnson and Goodrich proposed using an exponential formula of the form, $V = CR^pS^q$, and gave values of C and p, making q uniformly equal to 0.5 for simplicity.† This type of formula has also been advanced by Manning for open channels:

$$V = \frac{1.49}{n} R^{0.67}\, S^{0.5},‡$$

and by others for closed conduits.

For example,§ Lampe...... $V = 77.68\, D^{0.694}\, S^{0.555}$;

Flamant..... $V = (76.28 \text{ to } 86.38)\, D^{\frac{5}{7}}\, S^{\frac{4}{7}}$;

Williams.... $V = 67.7\, D^{0.668}\, S^{0.535}$;

Moritz...... $V = 77\, D^{0.7}\, S^{0.555}$.

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* Parker, "The Control of Water", p. 474.

† *Engineering Record,* Vol. 64, p. 542, November 4th, 1911.

‡ Parker, "The Control of Water", p. 472.

§ *Engineering Record,* Vol. 68, p. 669, December 13th, 1913.

A formula of this type is selected for the purposes of this paper. as it is easily deduced by plotting on logarithmic paper, as follows:

$$V = C\,R^p\,S^{0.5}.$$

$$\frac{V}{S^{0.5}} = C\,R^p.$$

$$\log.\frac{V}{S^{0.5}} = \log.\,C + p\,\log.\,R,$$

which is the equation of a straight line.

In recommending values of n for channels, the authors of *Bulletin No. 194* have classified them according to different types. Their classification has been adhered to in copying their data into Table 1, but only five of the twenty-three columns of data, which are of immediate use in this paper, are given. The first, second, fourth, fifth, and sixth columns of Table 1 were copied from the bulletin, and the third, seventh and eighth were computed by the writer. These data were plotted on Plates I and II and Figs. 1 and 2, each point being marked for identification with its assigned value of n. Curves (or rather straight lines) were drawn through these points for each type of channel, and from these the values of the coefficient, C, and the angle, α, in Table 2 were taken.

TABLE 1.

Concrete, Type I.

"n = 0.012 for the highest grade of material and workmanship and exceptionally good conditions. The surface of the lining to be as smoth to the hand as a troweled sidewalk. The expansion joints to be so well covered that they practically fulfill the same condition. The climate and water to be such that moss does not accumulate to any great extent. The water to be practically free from shifting material. The alignment to be composed of long tangents joined by spiraled curves, while the interior of the channel must be of uniform dimensions, true to grade throughout the cross-section."

No. of experiment.	Measured velocity.	Velocity by formula: $V = 123.7\,R^{0.69}\,S^{0.5}$.	Radius.	Slope.	n.	$S^{0.5}$.	$C\,R^p$.
1	5.48	4.92	5.23	0.0001611	0.0101	0.0127	431.0
4	20.62	17.77	1.30	0.0144	0.0108	0.1200	171.8
6	2.81	2.46	0.83	0.00051	0.0108	0.0226	124.3
7	2.71	2.44	0.82	0.00051	0.0111	0.0226	119.9
8	4.74	4.39	1.37	0.00082	0.0113	0.0286	165.5
9	15.78	14.29	0.94	0.01459	0.0115	0.1207	130.7
11	4.15	3.89	2.81	0.0002371	0.0110	0.0154	269.5
12	3 65	3.71	2.54	0.0002508	0.0121	0.0158	231.0
14	4.14	4.34	2.91	0.000283	0.0124	0.0168	246.4
16	15.05	15.09	0.29	0.08244	0.0124	0.2871	52.6
18	19.70	19.20	0.86	0.02971	0.0123	0.1723	114.3
19	12.87	13.03	0.49	0.02978	0.0125	0.1725	74.6

TABLE 1.—(*Continued.*)

CONCRETE, TYPE II.

"$n = 0.013$ for construetion as in Type I, but with curves as in the usual mountain canyon. Same construction and alignment as in type I, but with a small amount of sand or débris in water. Construction as in type III, but in very favorable alignment or for water that carries a small amount of fine silt that will eventually form a slick coat."

No. of experiment.	Measured velocity.	Velocity by formula: $V = 114.0\ R^{0.69}\ S^{0.5}$.	Radius.	Slope.	n.	$S^{0.5}$.	$C\ R^{p}$.
2	3.81	3.85	2.45	0.0003333	0.0130	0.0182	209.0
10	5.01	4.88	1.31	0.00126	0.0128	0.0355	141.0
13	3.65	3.64	2.54	0.0002837	0.0129	0.0168	217.0
15	2.45	2.47	1.30	0.000329	0.0132	0.0181	135.0
17	6.18	6.68	0.10	0.08244	0.0130	0.2871	21.5
20	2.06	2.06	0.58	0.0007	0.013	0.0264	78.0
21	7.10	7.19	2.13	0.0014	0.0132	0.0374	189.8

CONCRETE, TYPE III.

"$n = 0.014$ for linings made by good construction under favorable conditions. The surface to be as left by smooth-jointed forms or to be roughly troweled. Joints to be good, but causing some retardation. Alignment about equal in curves and tangents, with no spirals between. The bed to be clean and sides free from rough deposits."

The authors of the bulletin believe this is the proper value to use for most linings on moderate-sized channels.

No of experiment.	Measured velocity.	Velocity by formula: $V = 105.8\ R^{0.69}\ S^{0.5}$.	Radius.	Slope.	n.	$S^{0.5}$.	$C\ R^{p}$.
5	19.13	18.78	1.36	0.0206	0.0140	0.1435	133.2
22	7.15	7.46	2.12	0.00177	0.0142	0.0420	170.0
24	16.38	......	0.22	0.02056	0.0139	0.1434	114.2?
25	8.21	8.57	5.43	0.0006389	0.0138	0.0252	325.0
26	3.82	3.86	2.34	0.000413	0.014	0.0203	188.1
27	3.89	3.50	1.50	0.000626	0.0144	0.0250	155.6?
30	2.55	2.62	1.25	0.0004497	0.0143	0.0212	120.3

CONCRETE, TYPE IV.

"$n = 0.015$ for construction as in type III, but with sharp curves and clean bottom or moderate curves and much débris on the bottom but clean-cut sides."

No. of experiment.	Measured velocity.	Velocity by formula: $V = 98.4\ R^{0.69}\ S^{0.5}$.	Radius.	Slope.	n.	$S^{0.5}$.	$C\ R^{p}$.
3	4.68	4.93	3.88	0.0003875	0.0154	0.0197	237.5
28	3.34	3 24	1.50	0.000619	0.0146	0.0249	134.1
29	3.94	4.08	2.07	0.000629	0.0154	0.0251	157.0
31	3.86	3.87	1.94	0.00062	0.0149	0.0249	155.0

TABLE 1.—(*Continued.*)

CONCRETE, TYPE V.

"n = 0.016 for concrete as constructed by the average gang of laborers, using forms that leave prominent lines at the cracks, no finish coat being applied. Bed to have the usual small amount of rock fragments and patches of sand and gravel. Average amount of curvature. In climates where a rough deposit accumulates, as in southern California, a lining that originally had a value of n about 0.013 quickly assumes about this type."

No. of experiment.	Measured velocity.	Velocity by formula: $V = 92.1\ R^{0.69}\ S^{0.5}$.	Radius.	Slope.	n.	$S^{0.5}$.	$C R^P$.
32	4.71	4.52	1.41	0.00151	0.0155	0.0388	121.4
33	15.52	15.47	0.51	0.07180	0.0158	0.2679	57.9
35	3.74	3.98	0.84	0.002375	0.0155	0.0488	76.6
36	2.62	2.62	0.82	0.00106	0.0157	0.0326	80.4
37	1.86	1.89	0.54	0.00099	0.0160	0.0315	59.0

CONCRETE, TYPE VI.

"n = 0.017 for roughly coated linings with uneven joints. This value also is applicable where rough deposits accumulate on the sides and conditions of alignment are poor."

No. of experiment.	Measured velocity.	Velocity by formula: $V = 86.0\ R^{0.69}\ S^{0.5}$.	Radius.	Slope.	n.	$S^{0.5}$.	$C R^P$.
34	11.32	11.83	0.38	0.07230	0.0171	0.2689	42.1
39	2.27	2.24	0.98	0.0007	0.0167	0.0264	86.0
40	1.38	1.44	0.52	0.000694	0.0171	0.0263	52.5
41	3.58	3.65	1.38	0.001157	0.0174	0.0340	105.3

CONCRETE, TYPE VII.

"n = 0.018 for very rough concrete with sharp curves and deposits of gravel and moss. A broken gradient, irregular cross-section, and the like, contribute to such a high value of n."

No. of experiment.	Measured velocity.	Velocity by formula: $V = 80.3\ R^{0.69}\ S^{0.5}$.	Radius.	Slope.	n.	$S^{0.5}$.	$C R^P$.
23	6.94	7.11	2.15	0.00273	0.0189	0.0522	133.0
38	1.71	1.89	0.58	0.001184	0.0192	0.0344	49.7
42	1.67	1.65	1.22	0.0003208	0.0176	0.0179	93.3
43	2.89	3.01	0.98	0.001444	0.0188	0.0380	76.0
44	2.83	2.94	0.95	0.001449	0.0188	0.0380	74.5
45	2.94	2.90	1.94	0.000525	0.0177	0.0229	128.4
46	3.02	3.16	1.90	0.000639	0.0187	0.0253	119.4
47	2.85	2.82	1.63	0.000629	0.0176	0.0251	113.5
48	2.87	3.02	1.62	0.000729	0.0190	0.0270	106.3
49	2.10	2.26	0.88	0.000950	0.0192	0.0308	68.2
50	2.04	2.40	0.91	0.001021	0.0206	0.0320	63.8
51	2.27	2.70	1.63	0.000574	0.0211	0.0240	94.6
52	1.22	1.57	0.70	0.00063	0.0218	0.0251	48.6
53	1.07	1.39	0.62	0.0005839	0.0220	0.0242	44.2
54	1.88	2.38	1.02	0.000851	0.0221	0.0292	64.4
55	1.79	2.44	1.60	0.000482	0.0231	0.0220	81.4
56	1.96	3.20	1.49	0.00092	0.0284	0.0303	64.6

TABLE 1.—(*Continued.*)

Wooden Channels, Type I.

"$n = 0.012$ for well-constructed, clean flumes with surfaced lumber for both siding and battens. All lumber to run longitudinally. Alignment to consist of long tangents with gentle curves between. Construction to be such that the grade line will remain uniform, preventing sags and wavy alignment. A flume without battens may have a slightly lower value of n, but this difference will be inappreciable if the added length of the wetted perimeter due to the battens is considered in the design. Some very smooth grades of roofing materials used as linings also give a slightly lower value of n, but not enough to consider. If flumes are calked with oakum or other stuffing, care must be used that none projects into the water section if a high degree of efficiency is to be maintained."

No. of experiment.	Measured velocity.	Velocity by formula: $V = 123.7\, R^{0.69}\, S^{0.5}$.	Radius.	Slope.	n.	$S^{0.5}$.	$C\, R^p$.
57	4.49	3.85	2.28	0.0003108	0.0103	0.0176	255.0
58	3.23	3.03	1.94	0.00024	0.0112	0.0155	208.4
59	5.79	5.46	1.35	0.001288	0.0115	0.0359	161.3
60	5.08	4.68	1.66	0.000713	0.0112	0.0267	190.3
61	3.80	3.53	1.11	0.000710	0.0114	0.0266	142.8
62	5.96	6.12	1.96	0.000965	0.0123	0.0311	191.6
64	9.12	8.82	1.90	0.00210	0.0117	0.0458	199.0
65	7.80	7.43	1.47	0.00213	0.0118	0.0461	169.0
69	14.31	...	0.23	0.01054	0.0122	0.1026	139.4?
70	2.32	2.44	1.92	0.00016	0.0125	0.0126	181.0

Wooden Channels, Type II.

"$n = 0.013$ for well-constructed, clean flumes of surfaced lumber and battens, following mountain contours, where the alignment will consist of about equal gentle curves and tangents. This value will also apply to flumes with alignment and grade as described in type I, but with vertical battens at intervals, with projecting calking or a slight amount of hardened asphalt or other water-proofing retarding the velocity."

No. of experiment.	Measured velocity.	Velocity by formula: $V = 114.0\, R^{0.69}\, S^{0.5}$.	Radius.	Slope.	n.	$S^{0.5}$.	$C\, R^p$.
63	5.81	5.61	2.12	0.000858	0.0126	0.0293	198.3
66	7.30	6.94	1.49	0.00213	0.0126	0.0462	158.0
67	7.93	7.66	1.72	0.00213	0.0127	0.0462	171.6
71	2.60	2.57	1.80	0.000225	0.0127	0.0150	173.3
72	2.08	2.09	1.96	0.000133	0.0129	0.0115	180.0
77	3.71	3.66	0.99	0.001044	0.0131	0.0323	114.8

Wooden Channels, Type III.

"$n = 0.014$ for flumes of very smooth interior, but with many bends or sharp curves. This value also applies to those of type I with a location such that a slight amount of hillside débris is unavoidable.

TABLE 1.—(*Continued.*)

Construction of type I, but with cracks poured with any water-proofing material that hardens in tapering drops, is also liable to come in this type. For type I except that unsurfaced lumber is used."

No. of experiment.	Measured velocity.	Velocity by formula: $V = 105.8\ R^{0.69}\ S^{0.5}$.	Radius	Slope.	n.	$S^{0.5}$.	$C\ R^p$.
73	2.67	2.60	2.24	0.00020	0.0135	0.0141	189.0
74	1.64	1.66	0.40	0.000868	0.0138	0.0295	55.6
75	6.21	6.17	1.66	0.00169	0.0141	0.0411	151.0
76	5.46	5.44	0.87	0.0032	0.0142	0.0566	96.5
78	3.44	3.57	1.06	0.001048	0.0145	0.0324	106.2

Wooden Channels, Type IV.

"n = 0.015 for flumes of unplaned lumber, but otherwise as of type II."

The authors of the bulletin believe this is about the value to use for the usual grade of construction in a mountain canyon where the flume will get about the usual grade of maintenance, with repairs made with irregular-shaped scraps of boards.

No. of experiment.	Measured velocity.	Velocity by formula: $V = 98.4\ R^{0.69}\ S^{0.5}$.	Radius.	Slope.	n.	$S^{0.5}$.	$C\ R^p$.
68	5.45	5.24	1.23	0.00213	0.0149	0.0462	118.0
79	3.34	3.34	1.08	0.001035	0.0150	0.0322	103.7
80	3.34	3.37	1.08	0.001054	0.0152	0.0325	102.8
81	1.54	1.55	0.93	0.000274	0.0150	0.0166	93.0
82	3.13	3.18	1.64	0.00053	0.0153	0.0230	136.0
84	4.08	4.03	0.90	0.001934	0.0149	0.0440	92.7

Wooden Channels, Type V.

"n = 0.016 for flumes of type IV where sharp bends rather than curves are installed. For flumes lined with rough roofing material and for the ordinary grade of construction on a flume that is built and generally left to care for itself. The kind of organization that is to operate the flume will determine this factor."

No. of experiment.	Measured velocity.	Velocity by formula: $V = 92.1\ R^{0.69}\ S^{0.5}$.	Radius.	Slope.	n.	$S^{0.5}$.	$C\ R^p$.
83	3.06	2.95	1.62	0.00053	0.0155	0.0230	133.0
85	3.99	3.93	0.93	0.002019	0.0156	0.0449	88.8
86	3.61	3.55	1.00	0.001479	0.0157	0.0385	93.7
87	4.35	3.87	0.87	0.002145	0.0157	0.0463	93.9
88	1.30	1.31	0.66	0.0003615	0.0159	0.0190	68.4
89	1.08	1.10	1.94	0.0000568	0.0163	0.0075	143.5
90	6.11	6.61	0.59	0.01069	0.0167	0.1034	59.1
91	1.60	1.70	1.04	0.0003249	0.0167	0.0180	88.8
92	0.65	0.83	0.33	0.00038	0.0184	0.0195	33.3
93	1.22	1.50	2.30	0.000084	0.0191	0.0092	133.0
94	3.58	4.57	0.72	0.003915	0.0196	0.0626	57.2
95	2.97	3.80	2.86	0.0004	0.0201	0.0200	148.5
96	1.56	2.08	0.86	0.0006299	0.0202	0.0251	62.2
97	2.46	3.41	2.94	0.00031	0.0217	0.0176	140.0

TABLE 1.—(*Continued.*)

METAL FLUMES, TYPE I.

$n = 0.011$ for flumes "having countersunk joints between the various sheets of metal so that there is practically no added roughness presented to the water"; "in favorable alignment and clean."

No. of experiment.	Measured velocity.	Velocity by formula: $V = 137.0\ R^{0.69}\ S^{0.5}$.	Radius.	Slope.	n.	$S^{0.5}$.	$C\ R^{p}$.
98	6.01	4.97	0.37	0.0052	0.0099	0.0721	84.2
99	5.34	4.68	0.61	0.0023	0.0101	0.0480	111.4
100	1.66	1.56	0.38	0.0005	0.0106	0.0223	74.4
101	2.37	2.48	0.41	0.00113	0.0117	0.0336	70.5
102	2.55	2.53	0.41	0.00117	0.0112	0.0342	74.5
103	2.88	2.60	0.32	0.00175	0.0122	0.0418	68.9
104	4.40	4.97	0.69	0.0022	0.0126	0.0469	93.8

METAL FLUMES, TYPE II.

$n = 0.015$ for flumes "having joints that project into the water section presenting a shoulder every few feet that effectually retards the velocity"; "in favorable alignment and clean."

No. of experiment.	Velocity.		Radius.	Slope.	n.	$S^{0.5}$.	$C\ R^{p}$.
105	1.82	....	0.32	0.00120	0.0127	0.0346	52.5
106	1.43	....	0.84	0.00020	0.0129	0.0141	101.0
107	1.38	....	0.91	0.000175	0.013	0.0132	104.5
108	1.68	....	0.31	0.00130	0.0139	0.0360	46.6
109	5.35	....	1.07	0.00386	0.0179	0.0621	86.1
110	5.77	....	0.92	0.00537	0.0177	0.0733	78.7
111	5.10	....	0.84	0.00411	0.0166	0.0641	79.6

METAL FLUMES, TYPE III.

$n = 0.022$ for flumes "having regular corrugations at right angles to the axis of the flume"; "in favorable alignment and clean".

No. of experiment.	Velocity.		Radius.	Slope.	n.	$S^{0.5}$.	$C\ R^{p}$.
112	1.92	....	1.04	0.000892	0.0222	0.0299	64.2

EARTH CANALS, TYPE I.

"$n = 0.016$ for excellent conditions of earth channels. The velocity to be so low that a slick deposit of silt may accumulate, or the natural material be such as to become smooth when wet. The influence of vegetation at the edges to be a minimum. The water to be free from moss and other aquatic growth. The alignment to be free from bends and sharp curves."

TABLE 1.—(*Continued.*)

No. of experiment.	Measured velocity.	Velocity by formula: $V = 92.1\ R^{0.69}\ S^{0.5}$.	Radius.	Slope.	n.	$S^{0.5}$.	$C\ R^p$.
118	4.75	3.05	3.88	0.00017	0.012	0.0130	365.0
119	2.56	2.09	2.40	0.000154	0.0130	0.0124	206.0
120	2.22	2.32	2.62	0.00017	0.0164	0.0130	170.0
121	3.62	3.04	2.49	0.00031	0.0134	0.0176	205.5
122	1.04	0.90	0.86	0.00012	0.0135	0.0109	95.0
123	2.36	2.32	1.86	0.00027	0.0155	0.0164	143.5
124	2.02	2.10	1.60	0.000273	0.0164	0.0165	122.0
125	1.86	1.95	1.13	0.00038	0.0165	0.0195	95.4
126	1.28	1.43	2.20	0.0000804	0.0166	0.0090	142.5
127	0.93	1.06	0.99	0.0001341	0.0170	0.0116	80.2
128	2.94	2.99	2.84	0.00025	0.0170	0.0158	186.0
130	2.45	2.70	2.60	0.000230	0.0174	0.0152	161.5
131	1.96	2.18	1.11	0.00049	0.0176	0.0221	88.5
132	1.14	1.35	0.47	0.000617	0.0180	0.0248	46.0
134	2.30	2.66	2.12	0.000295	0.0181	0.0172	133.7
135	2.72	3.14	2.04	0.000438	0.0182	0.0209	130.0
136	2.58	3.00	1.20	0.00083	0.0184	0.0288	89.6

Earth Canals, Type II.

"$n = 0.020$ for well-constructed canals in firm earth or fine, packed gravel where velocities are such that silt may fill the interstices in the gravel. The banks to be clean-cut and free from disturbing vegetation. The alignment to be reasonably straight."

No. of experiment.	Measured velocity.	Velocity by formula: $V = 70.0\ R^{0.69}\ S^{0.5}$.	Radius.	Slope.	n.	$S^{0.5}$.	$C\ R^p$.
129	2.46	2.29	1.73	0.00050	0.0194	0.0224	109.8
133	0.97	0.93	0.50	0.000460	0.0186	0.0214	45.3
137	1.46	1.32	2.34	0.000111	0.0186	0.0105	138.5
138	1.88	1.75	2.79	0.000152	0.0193	0.0123	152.5
139	2.10	1.94	2.8	0.0001867	0.0194	0.0136	154.0
140	1.67	1.63	2.85	0.000127	0.0199	0.0113	148.0
141	2.56	2.34	2.41	0.00033	0.0188	0.0182	140.6
142	0.42	0.45	0.71	0.000067	0.0192	0.0082	51.2
143	1.14	1.13	0.50	0.00068	0.0194	0.0261	43.7
144	1.94	1.82	1.07	0.00062	0.0195	0.0249	77.9
145	1.85	1.77	2.20	0.000215	0.0196	0.0147	126.0
146	1.08	1.08	1.40	0.00015	0.0197	0.0122	88.5
147	1.51	1.49	1.69	0.00022	0.0200	0.0148	102.0
148	1.01	1.05	0.52	0.00056	0.0201	0.0237	42.6
149	0.67	0.71	1.04	0.000098	0.0202	0.0099	67.7
150	0.54	0.65	0.14	0.00135	0.0204	0.0367	14.7
151	2.56	2.52	2.85	0.000308	0.0204	0.0175	146.0
152	0.91	0.87	0.57	0.00034	0.0204	0.0184	49.5
153	1.74	1.87	0.33	0.00334	0.0205	0.0578	30.1
154	1.17	1.21	0.95	0.00032	0.0206	0.0179	65.3
155	2.00	2.02	2.03	0.00312	0.0208	0.0177	113.0
156	2.14	2.19	1.74	0.00046	0.0211	0.0214	100.0
157	1.59	1.63	2.03	0.00020	0.0211	0.0141	112.5
158	0.78	0.84	0.88	0.000175	0.0212	0.0132	59.0

TABLE 1.—(*Continued.*)

EARTH CANALS, TYPE III.

"n = 0.0225, although carried to one more significant figure, is given for the reason that it has long been used for this type and the tests do not disclose any reason for changing. This value for the average well-constructed canal in material which will eventually have a medium-smooth bottom, with graded gravel, grass on the edges and average alignment or silt at both sides of the bed and scattered stones in the middle, or a smooth bottom with an average amount of grass and roots forming the sides. Hardpan in good condition, clay and lava-ash soil take about this value."

No. of experiment.	Measured velocity.	Velocity by formula: $V = 60.2\ R^{0.69}\ S^{0.5}$.	Radius.	Slope.	n.	$S^{0.5}$.	$C\ R^P$.
159	2.99	2.22	1.52	0.00077	0.0213	0.0277	89.8
160	0.43	0.41	2.90	0.0000107	0.0216	0.003275	131.2
161	2.09	1.90	1.80	0.00044	0.0216	0.0210	99.5
162	1.34	1.26	1.11	0.0003795	0.0217	0.0195	68.7
163	1.48	1.37	1.60	0.00027	0.0218	0.0164	90.0
164	0.82	0.76	2.99	0.0000345	0.0219	0.0059	139.0
165	1.55	1.44	1.88	0.00024	0.0219	0.0155	100.0
167	1.24	1.18	1.06	0.000357	0.0220	0.0189	65.6
168	1.66	1.56	1.52	0.00038	0.0220	0.0195	85.1
169	1.47	1.37	1.66	0.00026	0.0220	0.0161	91.2
170	3.86	3.60	1.42	0.00220	0.0221	0.0469	82.3
172	1.44	1.37	1.06	0.000481	0.0221	0.0219	65.7
173	2.08	1.93	3.69	0.0001682	0.0221	0.0130	160.0
174	2.00	1.86	2.13	0.000335	0.0221	0.0183	109.3
175	3.12	2.89	2.16	0.000798	0.0222	0.0282	110.4
176	1.19	1.13	1.52	0.00020	0.0224	0.0141	84.0
177	1.15	1.13	0.91	0.00040	0.0224	0.0200	57.5
178	2.09	1.97	2.13	0.000377	0.0225	0.0194	107.5
179	1.63	1.56	1.97	0.000262	0.0226	0.0162	100.6
180	1.78	1.75	1.11	0.0007365	0.0228	0.0271	65.5
181	0.71	0.75	0.48	0.00043	0.0229	0.0207	34.3
182	1.19	1.22	0.65	0.00075	0.0230	0.0274	43.4
183	1.38	1.40	0.71	0.000875	0.0230	0.0296	46.6
184	1.90	1.86	1.93	0.0003859	0.0231	0.0196	96.7
185	1.01	1.00	1.83	0.00012	0.0232	0.0109	92.1
186	2.82	2.82	1.65	0.001105	0.0236	0.0332	84.8

EARTH CANALS, TYPE IV.

"n = 0.025 for canals where the retarding influence of moss, growths of dense grass near the edges, or scattered cobbles begins to show. The value of n in earth channels where the maintenance is neglected commences at this value and rapidly goes up. This is a good value to use in the design of small head ditches or a small ditch to serve but one or two farms."

TABLE 1.—(*Continued.*)

No. of experiment.	Measured velocity.	Velocity by formula: $V = 52.8\ R^{0.69}\ S^{0.5}$.	Radius.	Slope.	*n*.	$S^{0.5}$.	$C\ R^p$.
187	1.90	1.74	0.71	0.00175	0.0238	0.0418	45.5
188	2.93	2.74	0.55	0.00616	0.0238	0.0785	37.3
189	1.97	1.80	1.62	0.0006	0.0246	0.0245	80.4
190	0.34	0.36	0.58	0.0001014	0.0246	0.0100	33.7
191	1.61	1.57	0.65	0.0016	0.0247	0.0400	40.2
192	1.00	1.04	0.43	0.001246	0.0248	0.0353	28.3
193	1.82	1.72	2.89	0.000248	0.0258	0.0157	115.5
194	1.75	1.71	1.29	0.000737	0.0259	0.0271	64.5
195	2.35	2.21	3.02	0.00038	0.0259	0.0195	120.5
196	0.84	0.92	0.35	0.0013	0.0260	0.0360	23.3
197	1.61	1.55	2.04	0.00032	0.0260	0.0179	90.0
198	1.72	1.72	1.20	0.000831	0.0262	0.0288	59.7
199	0.99	1.01	1.27	0.000263	0.0262	0.0162	61.1
200	2.67	2.57	2.38	0.00072	0.0264	0.0268	99.6
201	1.68	1.70	1.52	0.00058	0.0266	0.0241	69.7
202	1.57	1.58	1.57	0.0004783	0.0267	0.0219	71.7
203	1.69	1.70	1.69	0.00050	0.0267	0.0224	75.4
204	1.14	1.20	1.03	0.000493	0.0269	0.0222	51.3
205	1.41	1.54	0.59	0.001758	0.0270	0.0149	33.6
206	1.45	1.52	1.02	0.000812	0.0271	0.0285	50.9

EARTH CANALS, TYPE V.

"n = 0.030 for canals subject to heavy growths of moss or other aquatic plants. Banks irregular or overhanging with dense rootlets. Bottom covered with large fragments of rock, or bed badly pitted by erosion. Values of n between 0.025 and 0.030 also cover the condition where the velocity is so high that cobbles are kept clean and unpacked in the center of the canal, but silt deposits near the sides. For values above 0.030 the channel is much choked with vegetation, very irregular, crooked, overhung with dragging trees and grasses, or there is some other condition that should not be allowed to exist in a well-kept system."

No. of experiment.	Measured velocity.	Velocity by formula: $V = 44.4\ R^{0.69}\ S^{0.5}$.	Radius.	Slope.	*n*.	$S^{0.5}$.	$C\ R^p$.
166	1.56	1.38	2.04	0.00036	0.0281	0.0190	82.1
171	1.39	1.88	0.60	0.00362	0.0390	0.0602	23.1
207	1.23	1.13	0.83	0.000842	0.0277	0.0290	42.4
208	1.04	1.04	0.75	0.00082	0.0294	0.0286	36.3
209	1.32	1.59	0.47	0.003679	0.0274	0.0606	21.8
210	1.20	1.14	0.66	0.001168	0.0278	0.0342	35.1
211	1.26	1.12	1.81	0.00028	0.0280	0.0167	75.4
212	2.50	2.32	1.01	0.002683	0.0283	0.0518	48.3
213	2.36	2.31	0.91	0.003088	0.0284	0.0556	42.4
214	4.66	4.14	1.87	0.00366	0.0284	0.0605	77.0
215	0.87	0.84	0.69	0.000594	0.0290	0.0244	35.7
216	1.18	1.11	1.36	0.000411	0.0292	0.0203	58.1
217	1.69	1.70	0.56	0.0033	0.0293	0.0574	29.4
218	0.61	0.61	1.08	0.00017	0.0295	0.0130	46.7
219	0.87	0.83	1.15	0.00029	0.0299	0.0170	51.0

DATA ON CONCRETE CHANNELS

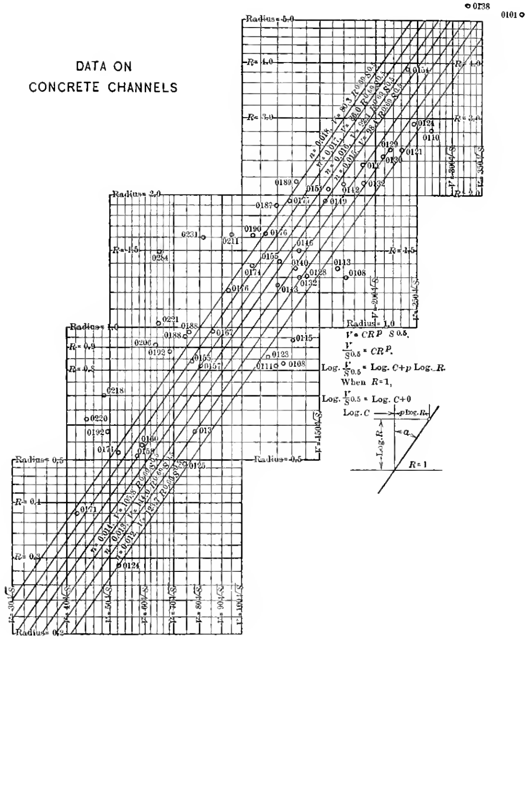

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TABLE 1.—(*Continued.*)
EARTH CANALS, TYPE V.—(*Continued.*)

No. of experiment.	Measured velocity.	Velocity by formula: $V = 44.4\ R^{0.69}\ S^{0.5}$.	Radius.	Slope.	n.	$S^{0.5}$.	$C\ R^{p}$.
220	1.09	1.13	0.83	0.00084	0.0308	0.0290	37.6
221	0.91	0.92	0.88	0.0005165	0.0300	0.0227	40.1
222	1.73	1.73	1.88	0.000634	0.0315	0.0252	68.6
223	1.60	1.66	1.22	0.0010647	0.0318	0.0326	49.0
224	1.37	1.62	1.32	0.0009095	0.0360	0.0301	45.3
225	0.88	1.01	0.49	0.0014	0.0319	0.0374	23.5
226	1.10	1.00	0.48	0.0014	0.0320	0.0374	29.4
227	1.16	1.18	2.06	0.00026	0.0321	0.0161	72.0
228	1.03	1.07	1.07	0.000533	0.0324	0.0231	44.6
229	0.43	1.53	0.52	0.000353	0.0329	0.0188	22.9
230	1.20	1.44	0.73	0.001629	0.0346	0.0403	29.8
231	1.12	1.31	0.93	0.00093	0.0349	0.0305	36.7
232	0.84	0.98	1.32	0.00033	0.0352	0.0182	46.1
233	1.18	1.42	1.32	0.0006982	0.0364	0.0264	44.7
234	1.44	1.67	1.87	0.00060	0.0371	0.0245	58.8
235	0.81	0.98	1.80	0.000217	0.0373	0.0147	55.0
236	1.18	1.47	1.39	0.000695	0.0379	0.0264	44.7
237	0.70	0.92	1.06	0.000398	0.0381	0.0199	35.0
238	0.44	0.63	0.77	0.00029	0.0393	0.0170	25.9
239	1.44	1.84	1.84	0.000746	0.0397	0.0273	52.7
240	0.45	0.70	0.40	0.000919	0.0399	0.0303	14.8
241	0.35	0.54	0.56	0.0003367	0.0403	0.0183	19.1
242	1.52	2.10	1.62	0·00115	0.0424	0.0339	44.8
243	0.65	1.05	0.68	0.00095	0.0436	0.0308	21.1
244	1.45	1.99	1.8	0.000894	0.0436	0.0299	48.5
245	0.40	0.54	3.90	0.000023	0.0461	0.0048	83.3
246	0.65	1.08	1.74	0.00028	0.0499	0.0167	38.9
247	0.42	0.87	0.48	0.00107	0.0519	0.0327	12.8
248	0.37	0.77	0.58	0.00064	0.0529	0.0253	14.6
249	0.32	0.73	0.52	0.00067	0.0544	0.0259	12.8

TABLE 2.

Type.		n.	C.	α.	Tan. α.	Weights.	Tan. α as weighted.
Concrete.	I........	0.012	128.0	32°30′	0.6371	0.7	0.44597
	II.......	0.013	113.5	34°15′	0.6809	0.8	0.54472
	III......	0.014	107.5	33° 0′	0.6494	0.8	0.51952
	IV......	0.015	99.0	33°30′	0.6619	0.7	0.46333
	V.......	0.016	91.5	35° 0′	0.7002	0.8	0.56016
	VI......	0.017	85.0	35°40′	0.7177	0.8	0.57416
	VII.....	0.018	80.0	34° 0′	0.6745	0.7	0.47215
Wood.....	I........	0.012	124.0	34° 0′	0.6745	0.5	0.33725
	II.......	0.013	114.0	34°30′	0.6873	0.6	0.41238
	III......	0.014	106.0	35°30′	0.7133	0.8	0.57064
	IV......	0.015	99.5	35°30′	0.7133	0.7	0.49931
	V.......	0.016	91.0	35°40′	0.7177	0.7	0.50239
Metal.....	I........	0.011	137.0	32°15′	0.6309	0.4	0.25236
	II.......	0.015	93.5	33°50′	0.6703	0.4	0.26812
	III......	0.022	.....	......	......	......	....
Earth.....	I........	0.016	90.5	34° 0′	0.6745	0.8	0.53960
	II.......	0.020	70.3	35°20′	0.7089	0.7	0.49623
	III......	0.0225	61.2	35°40′	0.7177	0.8	0.57416
	IV......	0.025	52.8	36°55′	0.7513	0.7	0.52591
	V.......	0.030	44.4	37°30′	0.7673	0.6	0.46038
Means					0.692	......	0.692
Sum..					......	13.0	....

Table 2, then, gives a series of disconnected formulas for the flow of water in various types of channels, whereas one formula, or at least a uniformly varying series, is desirable, both for simplicity and to eliminate errors. With this end in view, the coefficients, C, in Table 2, were plotted on Fig. 3, and certain coefficients were assumed, as shown

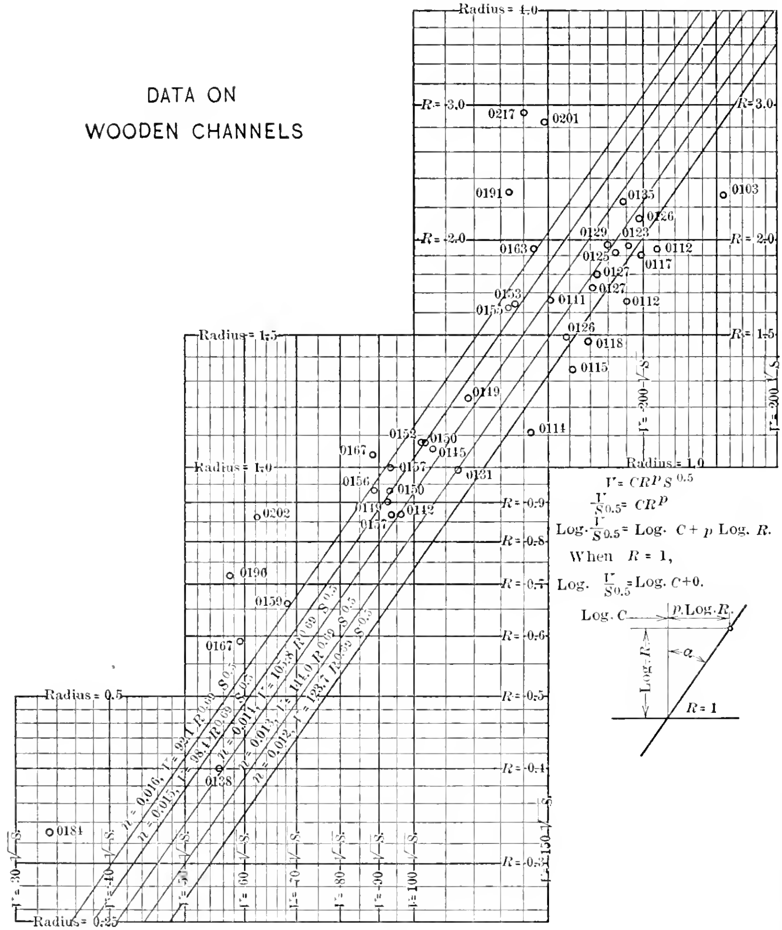


FIG. 1.

on that figure, varying on a smooth curve from 44.4 to 123.7. The exponents of R (the tangents of α in Table 2), plotted on Fig. 4, do not give so uniform a curve. The value of p might be taken as almost anything between $\frac{2}{3}$ and $\frac{3}{4}$, with little error, although the drawing shows that its value increases with that of n. It is thought that this variation might be eliminated by using a different exponent for the slope, but the writer does not know how to find that.*

DATA ON METAL FLUMES

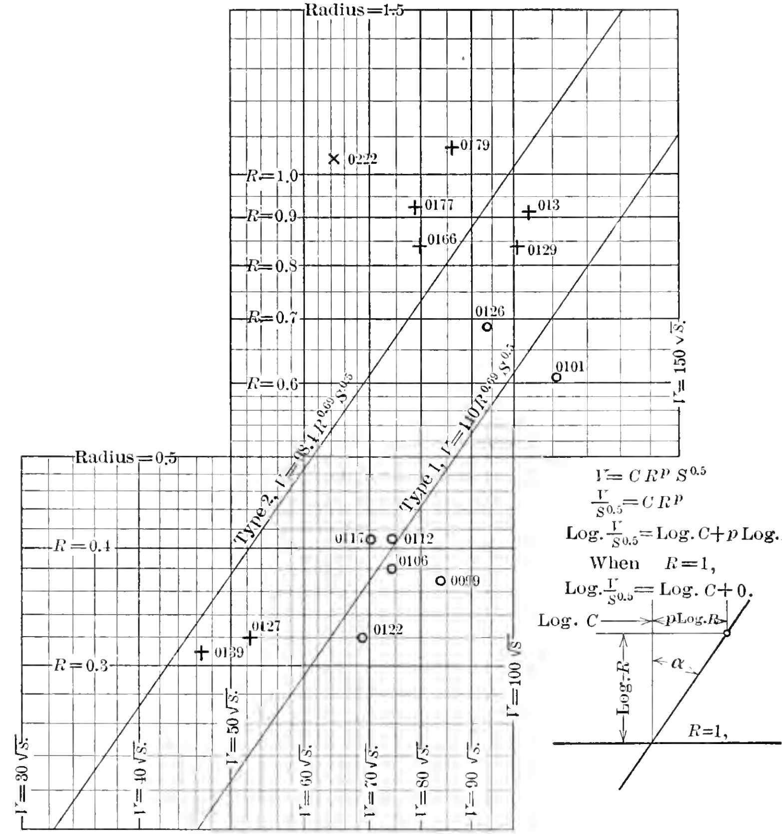
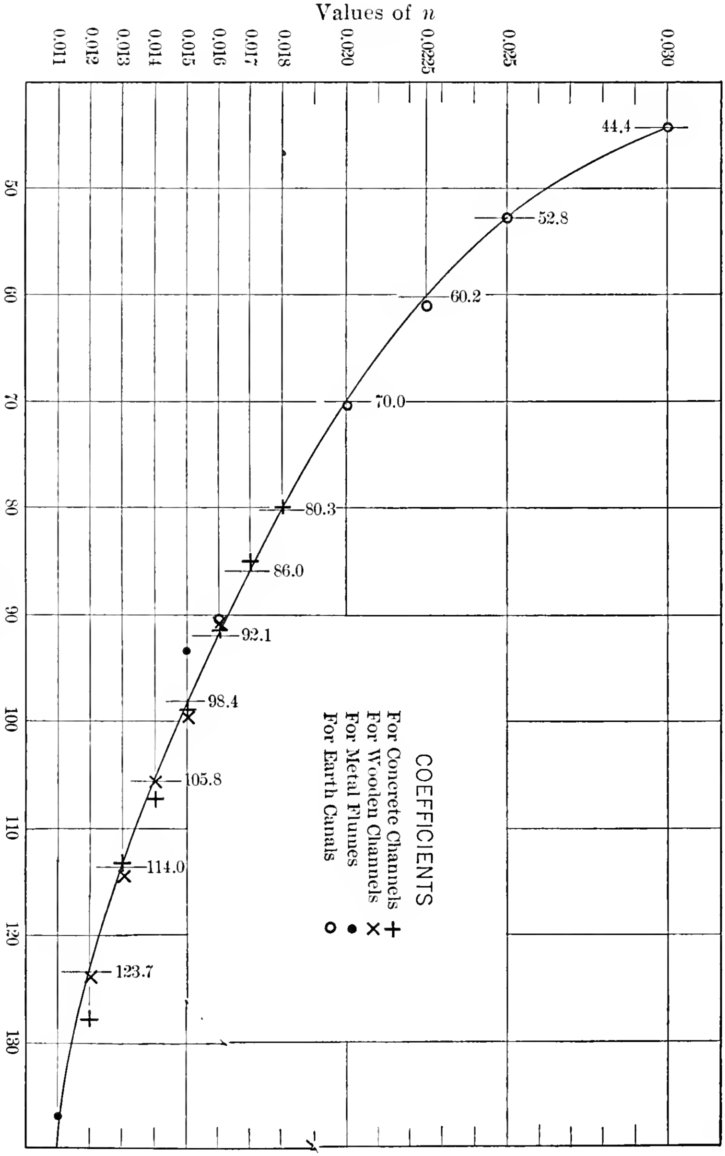


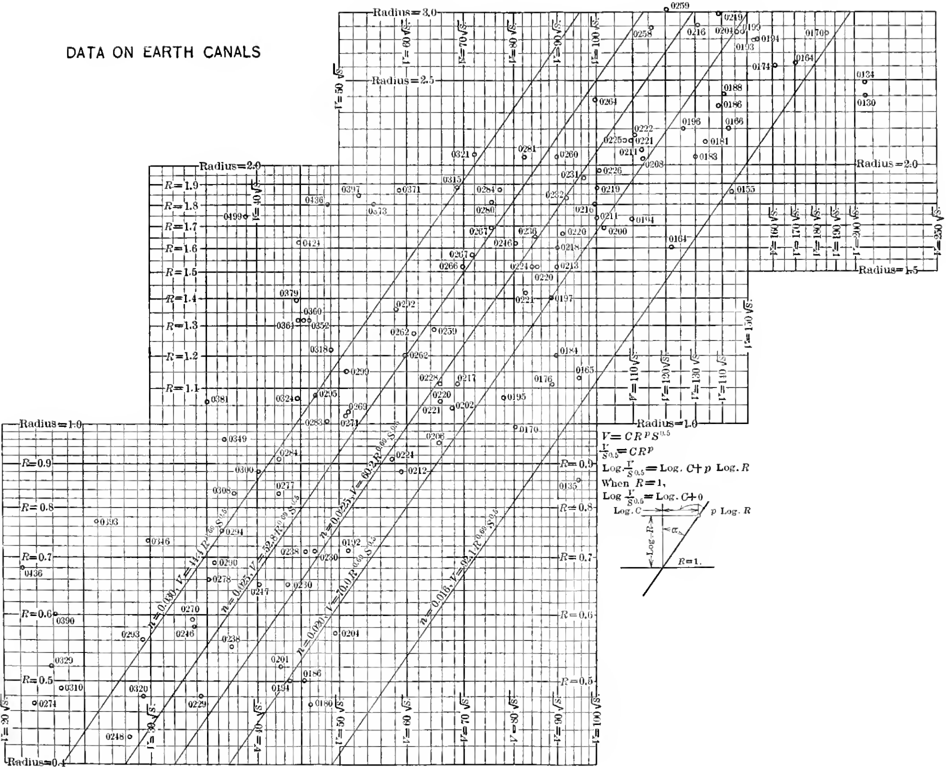
FIG. 2.

* The writer believes that the Office of Experiment Stations, during the summer of 1915, was gathering data on closed conduits similar to that in *Bulletin No. 194* on open channels. On a closed conduit which runs full, like a pressure pipe or siphon, the radius for a given diameter is constant, and does not vary with different velocities and slopes, the slopes being measured by the loss of head. The coefficient of roughness, of course, is a constant for any one conduit, so that the expression, $C R^p$, is constant. When those data are published, therefore, the ratings on each pipe can be plotted in the form, $V = (C R^p) S^q$, and the exponent of S can be determined. The average of these can then probably be applied to all the data, both in that bulletin and in this paper, and a new formula can be deduced, which, with the proper coefficient, will apply to all conditions of flow for either open or closed channels.



Values of C
FIG. 3.

DATA ON EARTH CANALS



Messrs. Johnson and Goodrich recognized this variation, and used different exponents of R for different types of channels. This adds to the complexity of the formula, and the writer doubts whether the added accuracy is worth it. The coefficient of roughness, n, will always be a matter for judgment, and it seems inconsistent to be too precise with one part of a formula when another part is so indefinite. If this variation of p can be reduced by a different exponent of S, it should

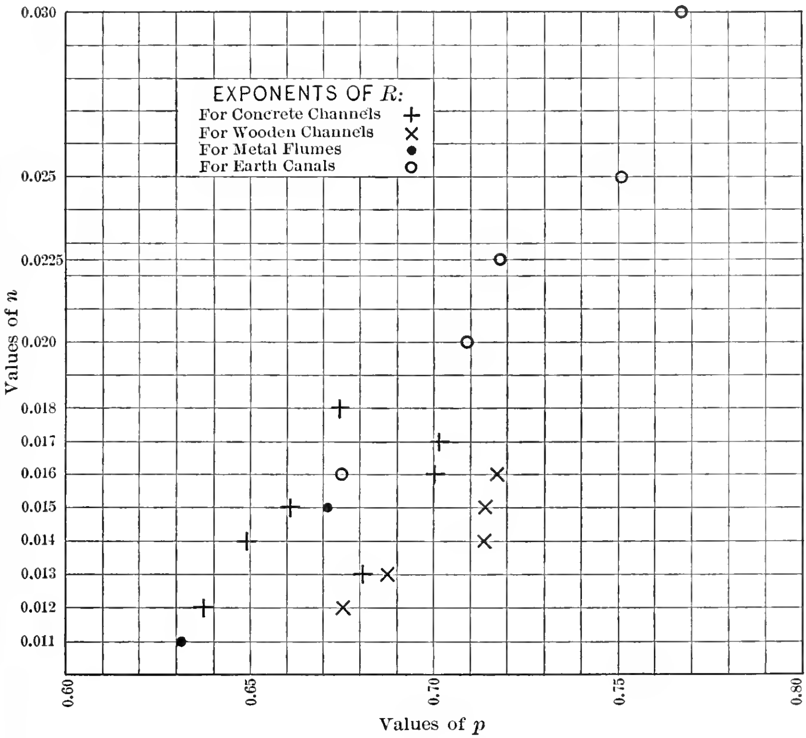


Fig. 4.

be done; but, to use a different exponent for each different type of channel makes the formula too cumbersome for ready use. The writer has merely averaged the tangents of α, in Table 2. Some of the lines by which they were obtained were more thoroughly established than others, and weights were applied accordingly, but the mean of the weighted tangents is the same as the mean of the others. The resulting formulas are represented by the diagonal lines on Plates I and II and

Figs. 1 and 2, and seem to fit the data fairly well. These formulas were used also in computing the theoretical velocities in the third column of Table 1, for ready comparison with the actual measured velocities.

Table 3, the 0.69th powers of radii, is added in order to aid in using or discussing these formulas.

TABLE 3.—0.69TH POWERS OF RADII.

R.	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.1	0.204	0.216	0.229	0.241	0.254	0.266	0.279	0.292	0.304	0.317
0.2	0.329	0.340	0.350	0.361	0.372	0.382	0.393	0.404	0.414	0.425
0.3	0.436	0.445	0.455	0.464	0.474	0.484	0.493	0.503	0.512	0.522
0.4	0.531	0.540	0.549	0.558	0.567	0.576	0.584	0.593	0.602	0.611
0.5	0.620	0.628	0.636	0.645	0.653	0.661	0.670	0.678	0.686	0.695
0.6	0.703	0.711	0.719	0.727	0.734	0.742	0.750	0.758	0.766	0.774
0.7	0.782	0.789	0.797	0.804	0.812	0.820	0.827	0.835	0.842	0.850
0.8	0.857	0.864	0.872	0.879	0.886	0.893	0.901	0.908	0.915	0.923
0.9	0.930	0.937	0.944	0.951	0.958	0.965	0.972	0.979	0.986	0.993
1.0	1.000	1.007	1.014	1.020	1.027	1.034	1.041	1.047	1.054	1.061
1.1	1.068	1.074	1.081	1.088	1.094	1.101	1.108	1.114	1.121	1.127
1.2	1.134	1.140	1.147	1.153	1.160	1.166	1.173	1.179	1.186	1.192
1.3	1.198	1.205	1.211	1.217	1.223	1.230	1.236	1.242	1.249	1.255
1.4	1.261	1.267	1.274	1.280	1.286	1.292	1.298	1.304	1.310	1.317
1.5	1.323	1.329	1.334	1.340	1.347	1.353	1.359	1.365	1.371	1.377
1.6	1.383	1.389	1.395	1.401	1.407	1.412	1.418	1.424	1.430	1.436
1.7	1.442	1.448	1.454	1.460	1.465	1.471	1.477	1.483	1.488	1.494
1.8	1.500	1.506	1.512	1.517	1.523	1.529	1.534	1.540	1.546	1.551
1.9	1.557	1.563	1.568	1.574	1.580	1.585	1.591	1.596	1.602	1.608
2.0	1.613	1.619	1.624	1.630	1.635	1.641	1.646	1.652	1.657	1.663
2.1	1.668	1.674	1.679	1.685	1.690	1.696	1.701	1.707	1.712	1.717
2.2	1.723	1.728	1.734	1.739	1.744	1.750	1.755	1.760	1.766	1.771
2.3	1.777	1.782	1.787	1.792	1.798	1.803	1.808	1.814	1.819	1.824
2.4	1.829	1.835	1.840	1.845	1.850	1.856	1.861	1.866	1.871	1.876
2.5	1.882	1.887	1.892	1.897	1.902	1.907	1.913	1.918	1.923	1.928
2.6	1.933	1.938	1.944	1.949	1.954	1.959	1.964	1.969	1.974	1.979
2.7	1.984	1.989	1.995	2.000	2.005	2.010	2.015	2.020	2.025	2.030
2.8	2.035	2.040	2.045	2.050	2.055	2.060	2.065	2.070	2.075	2.080
2.9	2.085	2.090	2.095	2.100	2.104	2.109	2.114	2.119	2.124	2.129
3.0	2.134	2.129	2.144	2.149	2.154	2.158	2.163	2.168	2.173	2.178
3.1	2.183	2.188	2.192	2.197	2.202	2.207	2.212	2.217	2.222	2.226
3.2	2.231	2.236	2.241	2.246	2.250	2.255	2.260	2.265	2.270	2.274
3.3	2.279	2.384	2.289	2.293	2.298	2.303	2.208	2.312	2.217	2.322
3.4	2.326	2.331	2.336	2.341	2.345	2.350	2.355	2.359	2.364	2.369
3.5	2.374	2.378	2.383	2.388	2.392	2.397	2.402	2.406	2.411	2.416
3.6	2.420	2.425	2.429	2.434	2.439	2.443	2.448	2.453	2.457	2.462
3.7	2.466	2.471	2.475	2.480	2.485	2.489	2.494	2.498	2.503	2.508
3.8	2.512	2.517	2.521	2.526	2.530	2.535	2.539	2.544	2.548	2.553
3.9	2.558	2.562	2.567	2.571	2.576	2.580	2.585	2.589	2.594	2.598
4.0	2.603	......	......	......	......	......	......	......	......	......

AMERICAN SOCIETY OF CIVIL ENGINEERS

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PAPERS AND DISCUSSIONS

METHOD OF DESIGNING A RECTANGULAR REINFORCED CONCRETE FLAT SLAB, EACH SIDE OF WHICH RESTS ON EITHER RIGID OR YIELDING SUPPORTS

By A. C. Janni, M. Am. Soc. C. E.

To be Presented April 5th, 1916.

Synopsis.

This paper deals with the incorrect method generally followed in calculating the moments of a continuous reinforced concrete flat slab resting on a system of girders.

That the elastic displacement of the supports should not be ignored, is demonstrated by theory and by a practical application.

All building codes, as far as the writer knows, overlook this important fact, and something should be done to correct the error.

There is no possibility of giving fixed formulas for designing this kind of construction; only the general lines of the method to be followed can be indicated.

Let *EFGH,* Fig. 1, be a flat slab floor, the reinforcement being parallel to *EF* and *FG,* supported by four perimetral walls, *EF, FG, GH, HE*; four columns, *K, L, N, M*; and girders as shown.

Taking into consideration the portion, *KLNM,* of that slab, sup-

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings,* and, when finally closed, the papers, with discussion in full, will be published in *Transactions.*

pose, for the present, that the four girders, KL, LN, NM, MK, which support it, are absolutely rigid.

Suppose now that this slab is divided into two systems of beams: System a parallel to the side, KL, and System b parallel to the side LN, as shown in Fig. 1.

If this slab carries a uniform load, w, per square foot, it is clear that the deflection of the beams of System a will not be the same for all of them, but will decrease from the center of Span l toward the sides, KL and NM.

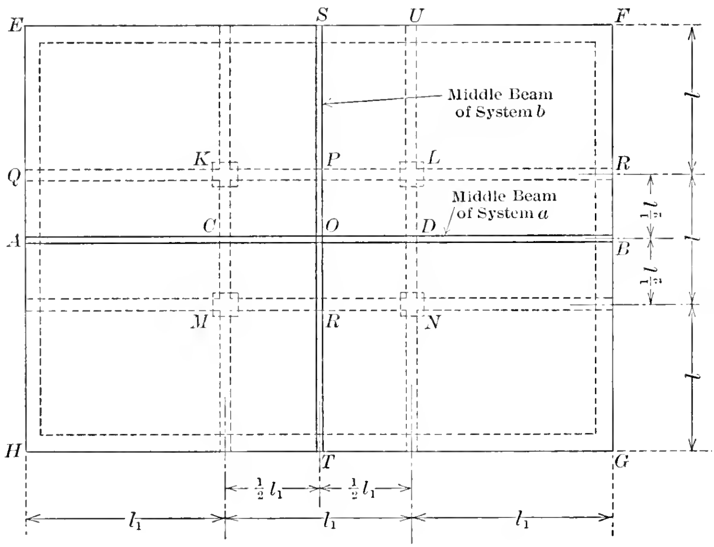

FIG. 1.

A similar condition will exist among the beams of System b.

Therefore, although these beams, a and b, are carrying the same uniform load, their deflections are different.

The solution of this problem, therefore, consists in finding a certain coefficient, α, by which the uniform load, w, should be corrected, in order to comply with the behavior of the slab.

Now, take into consideration the two beams, CD and PR. Each, being at the middle line of the slab, is the most deflected of its system; and, for the above consideration, if w is the uniform load assumed, $\alpha\ w$ will be the load at the center of the span, and w the load at the ends. Then $(1 - \alpha)\, w$ will be the load at the center of the span of the other beam, and w that at its ends.

It will be assumed that the law of variation of the load is a parabolic one.

Let PO, Fig. 2, be the half span, PO, of PR, Fig. 1; this half beam, on account of the symmetry of the beam, PR, may be regarded as a cantilever fixed at P and under the action of a hyperstatic moment, M_O.

If F is an ideal force applied to the cantilever at O, the work of deformation, D, is given by:

$$D = \frac{d\, L}{d\, F} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

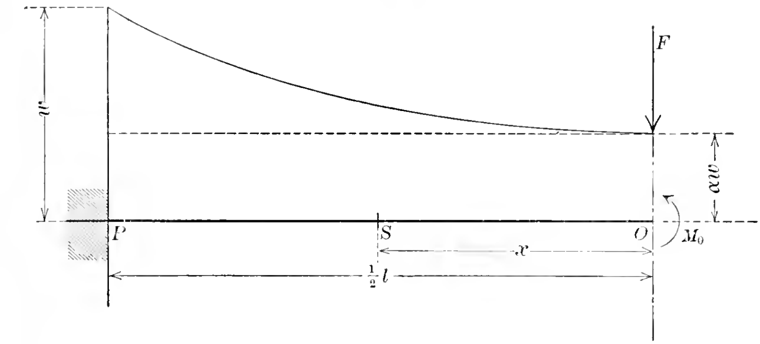

Fig. 2.

Disregarding the deformation caused by shear, and calling $\frac{1}{m}$ the coefficient of Poisson, it is known that the expression of the work, L, is given by:

$$L = \int_0^{\frac{l}{2}} \frac{m^2 - 1}{m^2} \times \frac{M^2\, dx}{2\, E\, I} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Equation (1), therefore, may be written:

$$D = \frac{m^2 - 1}{m^2\, E\, I} \int_0^{\frac{l}{2}} M \frac{d\, M}{d\, F}\, dx \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

For any generic section, S, Fig. 2, the value of M and $\frac{d\, M}{d\, F}$ are given by:

$$\left.\begin{aligned} M &= M_O - \alpha\, w\, \frac{x^2}{2} - \frac{w}{3}\,(1 - \alpha)\,\frac{x^4}{l^2} - F_x \\ \frac{d\, M}{d\, F} &= -\, x \end{aligned}\right\} \quad \ldots\ldots\ldots (4)$$

In the foregoing expression of M there is the unknown quantity, M_O, which may be determined by the condition that the derivative of the work, L, of deformation, with respect to the hyperstatic moment, M_O, must be zero, that is to say:

$$\frac{d\,L}{d\,M_O} = 0 \qquad \qquad (5)$$

Taking the value of L from Equation (2), then Equation (5) will become:

$$\int_0^{\frac{l}{2}} M \frac{d\,M}{d\,M_O}\,dx = 0 \qquad \qquad (6)$$

where:

$$\left. \begin{array}{l} M = M_O - \alpha\,w\,\dfrac{x^2}{2} - \dfrac{w}{3}(1-\alpha)\,\dfrac{x^4}{l^2} \\ \dfrac{d\,M}{d\,M_O} = 1 \end{array} \right\} \qquad \qquad (7)$$

Substituting in Equation (6) the values given by Equation (7), then Equation (6), after integration, may be written:

$$M_O = \frac{w\,l^2}{240}(1 + 9\,\alpha) \qquad \qquad (8)$$

Calling M_P the moment at P, Fig. 2, its value will be given by:

$$M_P = \frac{w\,l^2}{240}(1 + 9\,\alpha) - \frac{w\,l^2}{48}(1 + 5\,\alpha) \qquad \qquad (9)$$

Equation (3), after substituting in it the values given by Equations (4) and (8), performing the integration, and putting $F = 0$, will become:

$$E\,I\,D = \frac{m^2 - 1}{m^2} \times \frac{w\,l^4}{2\,880}(1 + 6.5\,\alpha) \qquad \qquad (10)$$

A similar expression can be obtained for the beam, $C\,D$, having the span, l_1; that is to say:

$$E\,I\,D = \frac{m^2 - 1}{m^2} \times \frac{w\,l_1^4}{2\,880}[1 + 6.5\,(1 - \alpha)] \qquad \qquad (11)$$

But the two beams, $P\,R$ and $C\,D$, must have the same deflection at O, therefore Equations (10) and (11) will furnish the other equation:

$$(1 + 6.5\,\alpha)\,l^4 = [1 + 6.5\,(1 - \alpha)]\,l_1^4$$

or

$$\alpha = \frac{7.5 - \left(\dfrac{l}{l_1}\right)^4}{6.5\left[1 + \left(\dfrac{l}{l_1}\right)^4\right]} \qquad \qquad (12)$$

Equation (12) becomes $\alpha = 1$, if $\frac{l_1}{l}$ is about $\frac{5}{3}$, that is to say, when the ratio, $\frac{L\ N}{K\ L}$, is larger than $\frac{5}{3}$, there is no advantage in the use of two-way reinforcement.

If $l = l_1$, then $\alpha = \frac{1}{2}$; that is to say, the advantage of two-way reinforcement is maximum when the slab is square.

As one cannot depend always on the effectiveness of the fixed end, P, the value of M_O, given by Equation (8), should be taken for the practical application of that equation, by assuming that the moment at P is only two-thirds of that given by Equation (9); therefore, this moment should be:

$$M_O = \frac{w\ l^2}{240}(1 + 9\ \alpha) + \frac{w\ l^2}{180}(1 + 4\ \alpha)$$

or

$$M_O = \frac{w\ l^2}{720}(7 + 43\ \alpha) \qquad \text{(13)}$$

The values of M_C and M_O, given by Equations (9) and (13), are those to be substituted in the general equation of stability given by theory:

$$f\ \frac{I}{h} = \frac{m^2 - 1}{m^2}\ M,$$

where, f = maximum allowable stress,

I = moment of inertia,

h = distance between neutral axis and the farther fiber,

m = coefficient of Poisson,

M = external moment.

Assuming $m = 4$, Equation (13) will become:

$$f\ \frac{I}{h} = \frac{15}{16}\ M \qquad \text{(14)}$$

Substituting in Equation (14), and giving to M the values found by Equations (9) and (13), the following equations are derived:

$$\left.\begin{aligned} f\frac{I}{h} &= \frac{w\ l^2}{64}(1 + 4\ \alpha) \quad \text{at } P \\ f\frac{I}{h} &= \frac{w\ l^2}{768}(7 + 43\ \alpha) \quad \text{at } O \end{aligned}\right\} \qquad \text{(15)}$$

If $l = l_1$, then, from Equation (12), $\alpha = \frac{1}{2}$, and Equations (15) will become:

$$f \frac{I}{h} = \frac{1}{21} w\, l^2 \ldots\ldots\ldots\ldots\ldots\ldots \text{at } P$$

$$f \frac{I}{h} = \frac{1}{27} w\, l^2 \ldots\ldots\ldots\ldots\ldots\ldots \text{at } O$$

Having obtained, in each case, the value of α from Equation (12), by using Equations (15), the moments at the center of the span and on the supports may be found, and the calculation of the sections of the slab may be carried out by the usual methods.

Thus far, the supports of the slab, *KLNM*, have been supposed to be rigid; and, as long as this rigidity is to be expected, Equations (12) and (15) may be used legitimately; but the problem, as stated at the beginning of the paper, goes a little farther.

In fact, the four girders, *KL*, *LN*, *NM*, *MK*, supporting the panel, *KLNM*, are not rigid; they deflect with the loading of the panel, or panels, and this deflection affects, in no negligible way, the external moments as given by Equations (15), as will be shown later.

Suppose the beam, *CD*, Fig. 1, to be extended on each end to *A* and *B*, the ends, *A* and *B*, of this ideal beam, *ACDB*, being supported by the walls, *EH* and *FG*.

If *D* is the deflection of the girder, *KM*, at the middle of its span, this deflection—considered as a deflection at *C* of the beam, *AB*—corresponds, according to theory, to a moment at Section *C* of this beam, given by:

$$M''_C = \frac{6}{5}\, E\, I_1 \frac{D_1}{l_1^2}.$$

Hence, at Section *C* of the beam, *AB*, there will be a total moment given by:

$$M_C = M'_C + M'_C.$$

The vertical reaction at *A* will be:

$$V_A = \frac{1}{2} w\, l_1 + \frac{M_C}{l_1},$$

and, therefore, the maximum moment of the span, *AC*, will be:

$$M_{AC} = \frac{V_A^2}{2\, w},$$

and the value of the moment at the middle of the span, CD, is found to be:

$$M_O = \left(V_A - \frac{3}{8}\,w\,l_1\right) l_1.$$

The reactions and moments for the beam, ST, are to be computed in a similar way.

The following is a practical application of the foregoing method:

Let $EFGH$, Fig. 1, be a floor system, as supposed herein, and, for a practical application of the formulas shown, let $l = 18$ ft. and $l_1 = 24$ ft.

The dead load plus live load will be assumed to be 300 lb. per sq. ft.

The moments acting on the ideal beam, PR, of the panel, $KLNM$, will be found first on the assumption that its supports at P and R are unyielding.

Equation (12) gives:

$$\alpha = 0.83.$$

Equations (15), consequently, give:

$$M_P = 6\ 561 \text{ ft-lb.}$$
$$M_O = 5\ 402.8 \text{ "}$$

The moments at C and O for the beam, CD, will be found to be:

$$M'_C = 4\ 588.1 \text{ ft-lb.}$$
$$M_O = 3\ 254.7 \text{ "}$$

Taking under consideration now the beam, CD, on account of the deflection of the girder, KM, the moment at C and, consequently, the moment at O, will assume other values which must be determined.

Admitting that the deflection of the girder, KM, at its middle point, C, is 0.06 in., the moment at C, M''_C, from the beam, AB, causing this deflection, is given by:

$$M''_C = \frac{6}{5} \times 2\ 000\ 000 \times 318 \times \frac{0.06}{288^2} = 552.8 \text{ ft-lb.}$$

Therefore, the total moment at C will be:

$$M_C = M'_C - M''_C = 4\ 588.1 - 552.8 = 4\ 035.2 \text{ ft-lb.}$$

and the vertical reaction at A will be given by:

$$V_A = \frac{1}{2}\,w\,l_1 + \frac{M_C}{l_1} = \frac{1}{2}\,300 \times 24 - \frac{4\ 035.2}{24} = 3\ 432\ ;$$

consequently, the moment (maximum) for the span, AC, and that at O for the span, CD, will be, respectively:

$$M_{AC} = \frac{3\,432^2}{2 \times 300} = 19\,631 \text{ ft-lb.}$$

$$M_O = 24\left(3\,432 - \frac{3}{8} \times 300 \times 24\right) = 17\,568 \text{ ft-lb.}$$

In a similar way, the moments relative to the beam, ST, could be corrected.

If the girders supporting these panels are imagined as suppressed, then the construction becomes what is commonly termed "Flat Slab Construction", the advantages of which have been rather exaggerated.

Of course, in the case of flat slab construction, beams like AB and ST would not have the greatest deflections, and other considerations should be necessary in order to carry out the design of this slab in a satisfactory way.

In the foregoing example, it will be noted, the variations of the moments of the beam, AB, due to the deflection of the girders, KL and MN, have not been taken into account.

The variations, or corrections, due to this deflection, which could be determined by the "Principle of Reciprocity" of Maxwell, together with the variations due to the deflection of the girders, KL and MN, as it has been shown in the foregoing, are enough to persuade a designer that the calculation of the moments in a reinforced concrete floor system cannot be carried out with any "ready made" set of formulas, but that each and every case is a problem by itself.

AMERICAN SOCIETY OF CIVIL ENGINEERS

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PAPERS AND DISCUSSIONS

TEMPERATURE STRESSES IN A SERIES OF SPANS*

By Tresham D. Gregg, Assoc. M. Am. Soc. C. E.

Synopsis.

The general problem of the temperature stresses in a series of spans arose while the writer was preparing plans for a viaduct at Little Rock, Ark., to carry a street over the tracks of the St. Louis, Iron Mountain and Southern Railroad. The type approved by the City and the Railroad Company was a series of six simple spans composed of girders covered and decked with concrete, and supported on solid concrete piers.

The proposal to build the three west spans of this viaduct integral with the piers and abutment, brought up the consideration of the temperature stresses.

This paper is a general solution of this problem by the method of least work and the Castigliano theorem for one, two, and three spans of variable stiffness and inelastic abutments, and an application of the general solution to this particular case.

A convenient method for the logarithmic computation of stresses is also given, and a brief discussion of the results of the investigation, with tables of constants and of computed stresses.

The writer hopes that the problem set forth in this paper may be of interest.

* This paper will not be presented at any meeting of the Society, but written communications on the subject are invited for subsequent publication in *Proceedings*, and with the paper in *Transactions*.

In the course of his work as Bridge Designer in the Bridge Engineer's office of the Chicago, Rock Island and Pacific Railway, the writer was required to prepare detailed plans for a viaduct at Little Rock, Ark., to carry West Third Street across the tracks of the St. Louis, Iron Mountain and Southern Railroad. The general outline of the bridge and the approximate length and character of the spans had been previously agreed upon by the two railroads concerned and the city authorities.

The type originally proposed by the City was a series of reinforced concrete arches. That finally agreed upon, however, was a series of simple spans, the outer girders of which had somewhat the appearance of arches (Figs. 1 and 2). Each of the three east spans is composed of eight steel girders covered and decked with reinforced concrete. Each of the three west spans is composed of eight reinforced concrete girders with integral reinforced concrete deck. All spans are supported by solid concrete piers, 3 ft. wide at the coping, all of which are on a more or less pronounced skew.

The problem arose from the proposal to build the three west spans integral with the piers and abutment, that is, without provision for changes in length due to temperature and shrinkage.

It is evident that such piers offer resistance to the free expansion or contraction of the spans which they support, and hence must introduce corresponding stresses. Are these stresses negligible? If they are not, and expansion must be provided for, how many joints are necessary, and where should they be placed?

It will be seen from Fig. 3 that although the piers are similar in design, they have different angles of skew, and therefore different degrees of stiffness in the line of the viaduct. The spans under consideration are of approximately constant section, except as to the quantity of steel reinforcement. The outer or sidewalk girders are continuous over the two intermediate piers. The other six are not.

Fig. 3 shows the average span lengths and the angles of skew of the piers. The areas of steel and concrete in the several spans, and the respective average moments of inertia of the piers about axes perpendicular to the axis of the bridge are given in Table 2. The heights of the piers in Fig. 1 are given from the base to the neutral plane of the spans, in each case. Although they vary somewhat, they are assumed to be equal, for simplicity in the calculations.

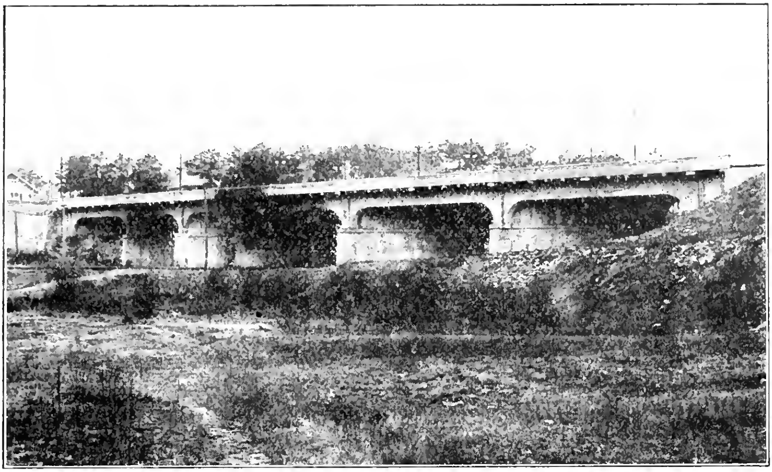


FIG. 1.—WEST THIRD STREET VIADUCT, LITTLE ROCK, ARK.

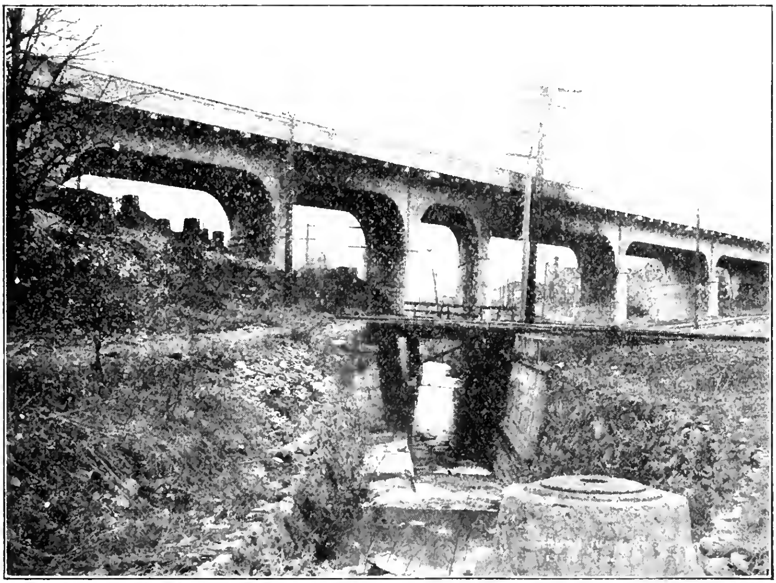


FIG. 2.—WEST THIRD STREET VIADUCT, LITTLE ROCK, ARK.

First, consider the simplest case—that of a single span held between solid, inelastic abutments, by frictionless pins axially placed, as shown in Fig. 4.

Case I.—One span on fixed, inelastic support. (Fig. 4.)

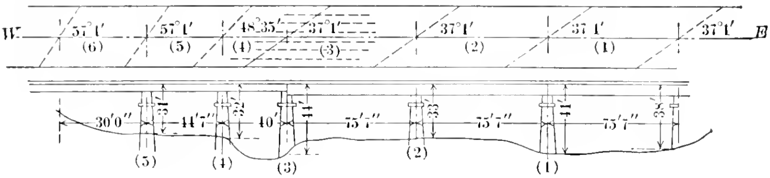


FIG. 3.

Let t equal the change of temperature, in degrees Fahrenheit;
e " " coefficient of expansion, in inches per inch per degree Fahrenheit;
E " " modulus of elasticity, in pounds per square inch;
A " " area of cross-section of span, in square inches;
l " " length of span, from center to center of piers, in inches.

Let T equal the total axial stress due to a temperature change of t degrees;
D " " change in length of span, if allowed to expand freely, $= t\ e\ l$.

Then
$$T = \frac{D\ A\ E}{l}.$$

Let
$$\frac{l}{A\ E} = C.$$

Substituting, we have:
$$T = \frac{D}{C}.$$

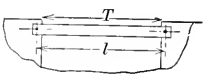


FIG. 4.

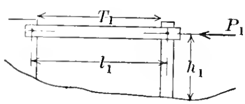


FIG. 5.

This must be added algebraically to the bending stresses in order to obtain the maximum fiber stress.

Case II.—One span fixed at both ends, one resting on an inelastic abutment, and the other on an elastic pier. (Fig. 5.)

Let the height of pier be h_1 inches; its moment of inertia, I_1; and its modulus of elasticity, E.

Suppose a force, P_1, to be applied axially with the span at the top of the pier. This force produces an axial stress, T_1, in the span, and bending stresses in the pier.

The deformation in the span due to the force, P_1, $= \frac{T_1\, l_1}{A\, E}$, and the work done $= \frac{T_1^2\, l_1}{2\, A\, E}$.

The deflection of the pier due to the load, $T_1 - P_1$, $= (T_1 - P_1)\frac{h_1^3}{3\, E\, I_1}$, and the work done $= (T_1 - P_1)^2\, \frac{h_1^3}{6\, E\, I_1}$.

The total work done $= U = \frac{T_1^2\, l_1}{2\, A\, E} + \frac{(T_1 - P_1)^2\, h_1^3}{6\, E\, I_1}$.

Differentiating with respect to T_1:

$$\frac{d\, U}{d\, T_1} = \frac{T_1\, l_1}{A\, E} + (T_1 - P_1)\, \frac{h_1^3}{3\, E\, I_1} \ldots\ldots\ldots\ldots (1)$$

Equating this to zero, by the principle of least work, T is found in terms of the force P_1.

If P_1 = zero, but the span changes in length, due to some other cause, such as a rise or fall in temperature, then, by Castigliano's theorem, the foregoing expression may be equated to the increment of length which the span would have if it were free from the restraint of the pier and abutment, that is,

$$\frac{T_1\, l_1}{A\, E} + \frac{T_1\, h_1^3}{3\, E\, I_2} = D_1 \ldots\ldots\ldots\ldots (2)$$

As before, let $\frac{l_1}{A\, E} = C_1$, and let $\frac{h_1^3}{3\, E\, I_1} = B_1$.

Substitute in Equation (2) and solve.

$$T_1 = \frac{D_1}{B_1 + C_1} \ldots\ldots\ldots\ldots (3)$$

Case III.—Single span, both supports elastic. (Fig. 6.)

The axial deformation of the span $= \frac{T_2\, l_2}{A\, E}$, and the work of deformation $= \frac{T_2^2\, l_2}{2\, A\, E}$.

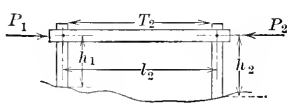


FIG. 6.

The deflection of Pier 1 $= (P_1 - T_2)\dfrac{h_1^3}{3EI_1}$, and the work of deflection $= (P_1 - T_2)^2\dfrac{h_1^3}{6EI_1}$.

The deflection of Pier 2 $= (T_2 - P_2)\dfrac{h_2^3}{3EI_2}$, and the work $= (T_2 - P_2)^2\dfrac{h_1^3}{6EI_1}$.

The total internal work:

$$U = (P_1 - T_2)^2\frac{h_1^3}{6EI_1} + \frac{T_2^2 l_2}{2AE} + (T_2 - P_2)^2\frac{h_2^3}{6EI_2}.$$

Differentiating with respect to T:

$$\frac{dU}{dT_2} = (-P_1 + T_2)\frac{h_1^3}{3EI_1} + \frac{T_1 l_2}{AE} + (T_2 - P_2)\frac{h_2^3}{3EI_2}.$$

Let P_1 and $P_2 = 0$, and, as before, placing the resulting expression equal to the unrestrained elongation, D_2,

$$\frac{T_2 h_1^3}{3EI_1} + \frac{T_2 l_2}{AE} + \frac{T_2 h_2^3}{3EI_2} = D_2 \quad\ldots\ldots\ldots\ldots\ldots(4)$$

Solving for T_2 and making the same substitutions as before:

$$T_2 = \frac{D_2}{B_1 + B_2 + C_2} \quad\ldots\ldots\ldots\ldots\ldots(5)$$

Case IV.—Two spans on one inelastic abutment, and two elastic piers. (Fig. 7.)

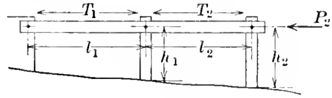


FIG. 7.

In a similar manner, the work of deformation due to the force $P_2 = U$.

$$U = \frac{T_1^2 l_1}{2AE} + (T_1 - T_2)^2\frac{h_1^3}{6EI_1} + \frac{T_2^2 l_2}{2AE} + (T_2 - P_2)^2\frac{h_2^3}{6EI_2}.$$

Taking the derivatives of U with respect to T_1 and T_2 successively:

$$\frac{dU}{dT_1} = \frac{T_1 l_1}{AE} + (T_1 - T_2)\frac{h_1^3}{3EI_1} = D_1 \quad\ldots\ldots\ldots\ldots(6)$$

$$\frac{dU}{dT_2} = (-T_1 + T_2)\frac{h_1^3}{3EI_1} + \frac{T_2 l_2}{AE} + (T_2 - P_2)\frac{h_2^3}{3EI_2} = D_2 . (7)$$

As before, making the B and C substitutions, we have:

$$(B_1 + C_1)\,T_1 - B_1 T_2 = D_1 \quad\ldots\ldots\ldots\ldots(8)$$
$$-B_1 T_1 + (B_1 + B_2 + C_2)\,T_2 = D_2 \quad\ldots\ldots\ldots\ldots(9)$$

Solving simultaneously for T_1 and T_2:

$$T_1 = \frac{(B + B_2 + C_2)\, D_1 + B\, D_2}{(B + C)\,(B + B + C)} \qquad \text{.............. (10)}$$

$$T_2 = \frac{B_1\, D_1 + (B_1 + C_1)\, D_2}{(B_1 + C_1)\,(B_1 + B_2 + C_2)} \qquad \text{.............. (11)}$$

If $\qquad B_1 = B_2 : \; D_1 = D_2 : \; C_1 = C_2$

$$T_1 = \frac{(3\, B + C)}{(B + C)\,(2\, B + C) - B_2}$$

$$T_2 = \frac{(2\, B + C)}{(B + C)\,(2\, B + C) - B_2} \qquad \text{.............. (11')}$$

And $$T_1 = \frac{3\, B + C}{2\, B + C}\, T_2 \qquad \text{.......................... (10')}$$

Case V.—Two spans; all supports elastic. (Fig. 8.)

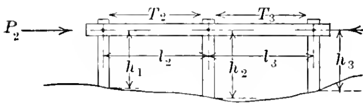


FIG. 8.

The work of deformation due to the forces, P_2 and P_3, $= U$.

$$U = (P_2 - T_2)^2 \frac{h_1^3}{6\, E\, I_1} + \frac{T_2^2\, l_2}{2\, A\, E} + (T_2 - T_3)^2 \frac{h_2^3}{6\, E\, I_2} + \frac{T_3^2\, l_3}{2\, A\, E} + (T_3 - P_3) \frac{h_3^3}{6\, E\, I_3}.$$

Taking successively the derivatives of U with respect to T_2 and T_3, and placing equal respectively to D_2 and D_3:

$$\frac{d\, U}{d\, T_2} = (-P_2 + T_2) \frac{h_1^3}{3\, E\, I_1} + \frac{T_2\, l_2}{A\, E} + (T_2 - T_3) \frac{h_2^3}{3\, E\, I_2} = D_2 \text{... (12)}$$

$$\frac{d\, U}{d\, T_3} = (-T_2 + T_3) \frac{h_2^3}{3\, E\, I_2} + \frac{T_3\, l_3}{A\, E} + (T_3 - P_3) \frac{h_3^3}{3\, E\, I_3} = D_3 \text{... (13)}$$

Letting P_2 and $P_3 = 0$, and making the B and C substitutions, we have:

$$(B_1 + B_2 + C_2)\, T_2 - B_2\, T_3 = D_2 \text{.............. (14)}$$

$$- B_2\, T_2 + (B_2 + B_3 + C_3)\, T_3 = D_3 \text{............ (15)}$$

Solving simultaneously for T_2 and T_3, we have:

$$T_2 = \frac{(B_2 + B_3 + C_3)\, D_2 + B_2\, D_3}{(B_1 + B_2 + C_2)\,(B_2 + B_3 + C_3) - B_2^2} \text{........ (16)}$$

$$T_3 = \frac{B_2\, D_2 + (B_1 + B_2 + C_2)\, D_3}{(B_1 + B_2 + C_3)\,(B_2 + B_3 + C_3) - B_2^2} \text{.......... (17)}$$

If

$$B_1 = B_2 = B_3 = B$$
$$C_2 = C_3 = C$$
$$D_2 = D_3 = D$$

$$T = \frac{D}{C + B} = T \text{ (= Case II).}$$

Case VI.—Three spans; one inelastic abutment, and three elastic piers. (Fig. 9.)

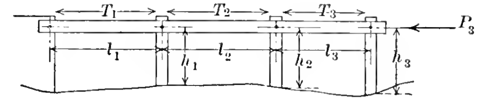


Fig. 9.

The work of deformation due to the external force, $P_3 = U$.

$$U = \frac{T_1^2\, l_2}{2\, A\, E} + (T_1 - T_2)^2 \frac{h_1^3}{6\, E\, I_1} + \frac{T_2^2\, l_2}{2\, A\, E} + (T_2 - T_3)^2 \frac{h_2^3}{6\, E\, I_2}$$
$$+ \frac{T_3^3\, l_3}{2\, A\, E} + (T_3 - P_3)^2 \frac{h_2^3}{6\, E\, I_2}.$$

Taking successively the derivatives of U with respect to T_1, T_2, and T_3, we have:

$$\frac{d\, U}{d\, T_1} = \frac{T_1\, l_1}{A\, E} + (T_1 - T_2)\frac{h_1^3}{3\, E\, I_1} = D_1 \ldots\ldots\ldots\ldots (18)$$

$$\frac{d\, U}{d\, T_2} = (-T_1 + T_2)\frac{h_1^3}{3\, E\, I_1} + \frac{T_2\, l_2}{A\, E} + (T_2 - T_3)\frac{h_2^3}{3\, E\, I_2} = D_2 \ldots (19)$$

$$\frac{d\, U}{d\, T_3} = (-T_2 + T_3)\frac{h_2^3}{3\, E\, I_2} + \frac{T_3\, l_3}{A\, E} + (T_3 - P_3)\frac{h_3^3}{3\, E\, I_3} = D_3 \ldots (20)$$

Letting $P_3 = 0$, and making the B and C substitutions, we have:

$$(B_1 + C_1)\, T_1 - B_1\, T_2 = D_1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (21)$$
$$-B_1\, T_1 + (B_1 + B_2 + C_2)\, T_2 - B_2\, T_3 = D_2 \ldots\ldots\ldots (22)$$
$$-B_2\, T_2 + (B_2 + B_3 + C_3)\, T_3 = D_3 \ldots\ldots\ldots\ldots\ldots (23)$$

Solving simultaneously for T_1, T_2, and T_3, we have:

$$T_1 = \frac{D_1 + B_1\, T_2}{B_1 + C_1} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (24)$$

$$T_2 = \frac{B_1\,(B_2 + B_3 + C_3)\, D_1 + (B_1 + C_1)\,(B_2 + B_3 + C_3)\, D_2 + (B_1 + C_1)\, B_2\, D_3}{(B_1 + C_1)\,(B_1 + B_2 + C_2)\,(B_2 + B_3 + C_3) - (B_1 + C_1)\, B_2^2 - B_1^2\,(B_2 + B_3 + C_3)} \ldots (25)$$

$$T_3 = \frac{D_3 + B_2\, T_2}{B_2 + B_3 + C_3} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (26)$$

If $$D_1 = D_2 = D_3 = D,$$
$$B_1 = B_2 = B_3 = B,$$
and $$C_1 = C_2 = C_3 = C,$$
then $$T_1 = \frac{D + B\,T_2}{B + C} \qquad (24')$$

$$T_2 = \frac{D\,(B\,(3\,B + C) + (B + C)\,(2\,B + C))}{(B + C)\,(2\,B + C) - B\,(3\,B + C)} \qquad (25')$$

$$T_3 = \frac{D + B\,T_2}{2\,B + C} \qquad (26')$$

And $$T_1 = \frac{(2\,B + C)\,T_3}{B + C} \qquad (26'')$$

Case VII.—Three spans; all supports elastic. (Fig. 10.)

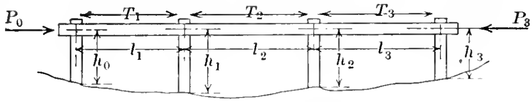


FIG. 10.

The work of deformation of the forces, P_0 and P_3, is equal to U.

$$U = (P_0 - T_1)^2 \frac{h_0^3}{6\,E\,I_0} + \frac{T_1^2\,l_1}{2\,A\,E} + (T_1 - T_2)^2 \frac{h_1^3}{6\,E\,I_1} + \frac{T_2^2\,l_2}{2\,A\,E}$$
$$+ (T_2 - T_3)^2 \frac{h_2^3}{6\,E\,I_2} + \frac{T_3^2\,l_3}{2\,A\,E} + (T_3 - P_3)^2 \frac{h_3^3}{6\,E\,I_3},$$

whence, $$\frac{d\,U}{d\,T_1} = (-P_0 + T_1) \frac{h_0^3}{3\,E\,I_0} + \frac{T_1\,l_1}{A\,E} + (T_1 - T_2) \frac{h_2^3}{3\,E\,I_2}$$

$$\frac{d\,U}{d\,T_2} = (-T_1 + T_2) \frac{h_1^3}{3\,E\,I_1} + \frac{T_2\,l_2}{A\,E} + (T_2 - T_3) \frac{h_2^3}{3\,E\,I_2}$$

$$\frac{d\,U}{d\,T_3} = (-T_2 + T_3) \frac{h_2^3}{3\,E\,I_2} + \frac{T_3\,l_3}{A\,E} + (T_3 - P_3) \frac{h_3^3}{3\,E\,I_3}$$

Making the usual substitutions, and equating to D_1, D_2, and D_3, respectively, we have:

$$(B_0 + B_1 + C_1)\,T_1 - B_1\,T_2 = D_1$$
$$-B_1\,T_1 + (B_1 + B_2 + C_2)\,T_2 - B_2\,T_3 = D_2$$
$$-B_2\,T_2 + (B_2 + B_3 + C_3)\,T_3 = D_3$$

Solving for T_1, T_2 and T_3:

$$T_1 = \frac{D_1 + B_1\,T_2}{(B_0 + B_1 + C_1)} \qquad (27)$$

$$T_3 = \frac{D_3 + B_2\,T_2}{B_2 + B_3 + C_3} \qquad (28)$$

$$T_2 = \frac{B_1 (B_2 + B_3 + C_2) D_1 + (B_0 + B_1 + C_1)(B_2 + B_3 + C_3) D_2 + (B_0 + B_1 + C_1) B_2 D_3}{(B_0 + B_1 + C_1)(B_1 + B_2 + C_2)(B_2 + B_3 + C_3) - (B_0 + B_1 + C_1) B_2^2 - B_1^2 (B_2 + B_3 + C_3)} \ldots\ldots (29)$$

If $D_1 = D_2 = D_3 = D$,

$B_1 = B_2 = B_3 = B$,

and $C_1 = C_2 = C_3 = C$,

then

$$T_2 = \frac{(4\,B + C)\,D}{(2\,B + C)^2 - 2\,B^2} \ldots\ldots\ldots\ldots (28')$$

$$T_1 = T_3 = \frac{D + B\,T_2}{2\,B + C} = D\,\frac{\left(1 + B\,\dfrac{4\,B + C}{(2\,B + C)^2 - 2\,B^2}\right)}{(2\,B + C)} \ldots (29')$$

$$= D\left(\frac{(2\,B + C)^2 - 2\,B^2 + B\,(4\,B + C)}{(2\,B + C)^3 - 2\,B^2\,(2\,B + C)}\right)$$

$$= \frac{D\,(6\,B^2 + 5\,B\,C + C^2)}{(2\,B + C)\,((2\,B + C)^2 - 2\,B^2)} = \frac{D\,(3\,B + C)}{((2\,B + C)^2 - 2\,B^2)}$$

$$= \frac{D\,(3\,B + C)}{(2\,B + C)^2 - 2\,B^2}; \text{ and } T_1 = T_3 = \frac{(3\,B + C)\,T_2}{4\,B + C} \ldots (29'')$$

Application of General Formulas.—The general formulas developed will now be applied to the determination of temperature stresses in the viaduct, the application being based on the following conditions:

First, the three concrete spans monolithic, supported without friction on Piers 3 and 4, and fixed with frictionless pins on Pier 5 and the west abutment. This is Case II.

Second, supported without friction on the abutment and Pier 3, and fixed on Piers 4 and 5. Case III.

Third, supported without friction on Pier 3, and fixed on Piers 4 and 5, and on the abutment. Case IV.

Fourth, supported without friction on the abutment and fixed on Piers 3, 4, and 5. Case V.

Fifth, fixed on all four supports. Case VI.

Proceeding now to the calculation of the various constants involved:

The constants required of each pier are: I, the moment of inertia about an axis perpendicular to the axis of the viaduct; E, the modulus of elasticity of the material; and h the height of the pier from the base to the neutral plane of the spans.

$I = I_A \sin.^2 L + I_B \cos.^2 L$, in which L is the angle made by the axis of the pier with the axis of I (perpendicular to the axis of the viaduct). I_A is the moment of inertia of the pier about its short axis, and I_B is the moment of inertia about its long axis.

E is taken as 3 000 000 lb. per sq. in., and h is assumed in all cases to be 40 ft.

The constant, $\frac{h}{3\ E\ I} = B$, has the following values :

Pier 3, $B_3 = 0.11268 \times 10^{-7}$ in., Log. 2.0518419 — 10 ;

Pier 4, $B_2 = 0.16333 \times 10^{-7}$ in., Log. 2.2130659 — 10 ;

Pier 5, $B_1 = 0.24132 \times 10^{-7}$ in., Log. 2.3825920 — 10.

The constants required of each span are :

A = area, in square inches ;

l = average length, in inches ;

E = its modulus of elasticity ;

e = its coefficient of expansion, these being combined into

$c = \frac{l}{A\ E}$ and $D = t\ e\ l$;

t = the range of temperature = 40° ;

e = 0.0000055.

Span 4 :

$C_3 = 0.1145 \times 10^{-7}$ in., Log. 2.0588055 — 10 ;

$D_3 = 0.10459$ in., Log. 9.0194902 — 10 ;

A = 13 960 sq. in. (including steel in terms of concrete).

Span 5 :

$C = 0.12798 \times 10^{-7}$ in., Log. 2.1071421 — 10 ;

$D = 0.11790$ in., Log. 9.0715138 — 10 ;

A = 13 960 sq. in.

Span 6 :

$C = 0.13990 \times 10^{-7}$ in., Log. 2.1458177 — 10 ;

$D = 0.132$ in., Log. 9.1205739 — 10 ;

A = 14 300 sq. in.

The foregoing constants are combined into the following terms, for convenience in substitution :

$C_1 + B_1 = 0.38122 \times 10^{-7}$, Log. 2.5811757 — 10 ;

$C_2 + B_1 + B_2 = 0.53263 \times 10^{-7}$, Log. 2.7264256 — 10 ;

$C_3 + B_2 + B_3 = 0.39051 \times 10^{-7}$, Log. 2.5916322 — 10 ;

${B_1}^2 = 0.58235 \times 10^{-15}$, Log. 4.7651840 — 20 ;

${B_2}^2 = 0.26677 \times 10^{-15}$, Log. 4.4261318 — 20.

The numerical calculations of the unit stresses in the concrete of Span 5, under the assumption of Case V, are here given to illustrate a convenient method of calculation.

Equation (16): $$T = \frac{D_2\,(C_3 + B_2 + B_3) + D_3\,B_2}{(C_2 + B_1 + B_2)\,(C_3 + B_2 + B_3) - B_2^2}$$

$$\begin{aligned}
\text{Log. } D_2 &= 9.0715138 - 10 \\
\text{Log. } (C_3 + B_2 + B_3) &= 2.5916322 - 10 \\
&\ 11.6631460 - 20 = 0.46041 \times 10^{-8}. \\
\text{Log. } D_3 &= 9.0194902 - 10 \\
\text{Log. } B_2 &= 2.2130659 - 10 \\
&\ 11.2325561 - 20 = 0.17083 \times 10^{-8} \\
&\ \text{Numerator} = 0.63124 \times 10^{-8} = N. \\
\text{Log. } (C_2 + B_1 + B_2) &= 2.7264256 - 10 \\
\text{Log. } (C_3 + B_2 + B_3) &= 2.5916322 - 10 \\
&\ 5.3180578 - 20 = 0.20800 \times 10^{-14} \\
&\ \text{Less} \quad B = 0.02668 \times 10^{-14} \\
&\ \text{Denominator} = 0.18132 \times 10^{-14} = D. \\
\text{Log. } N &= 11.8001945 - 20 \\
\text{Log. } D &= 5.2584457 - 20 \\
\text{Log. } T_2 &= 6.5417488 \quad T_2 = 3\,481\,400 \text{ lb.} \\
\text{Log. } A &= 4.1448854 \\
\text{Log. } f_c &= 2.3968634 \quad f_c = 250 \text{ lb. per sq. in.}
\end{aligned}$$

which is the average axial unit stress due to a change in temperature of 40°, and may be either compression or tension. The corresponding stress in the steel is $250 \times 10 = 2\,500$ lb. per sq. in.

The bending stress in Pier 5 for Case VI (that under consideration)

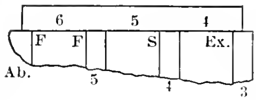
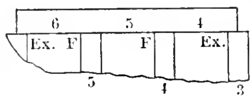
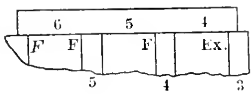
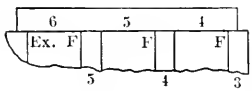
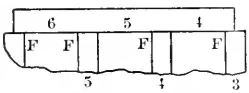
$$= \frac{M\,y}{I} = \frac{T_3\,h_3\,y}{I_3} = \frac{3\,481\,400 \times 480 \times 230}{509\,201\,000}$$

or $f_c = 755$ lb. per sq. in. in the extreme fiber. To this, of course, must be added algebraically the normal stress, in order to get the maximum and minimum.

The bending stresses have been found under the assumption of hinge joints at the piers. The original proposal, however, called for spans integral with the piers. As these girders, under such conditions, would be capable of transmitting considerable moment to the piers, the moment arm, h, of course, would be shortened; but the total stress, *T*, at the same time, would be correspondingly increased, owing to the increased stiffness of the pier (see Equation (5)), hence the resulting stresses would not be greatly changed under an assumption of partial or even complete continuity with the supports.

Table 1 shows the arrangements of expansion joints on the viaduct according to Cases II to VI, inclusive, with the corresponding unit axial stresses in the spans, and the bending stresses in the piers.

TABLE 1.

Case.	Diagram.	Average Stress in Spans.			Bending Stress in Piers.		
		6	5	4	5	4	
II		240	0	0	750	0	0
III		0	160	0	480	390	0
IV		480	400	0	145	1 090	0
V		0	250	300	755	115	600
VI		590	560	430	125	490	860

Ex. = Expansion joint; F = Fixed on pier; S = Sliding on pier.

Now return to the original question; that is, are the stresses due to temperature changes in this viaduct negligible?

Referring to Table 1, it is plain that, under the arrangement of Case VI, with all points of support fixed, a change of 40° Fahr. in temperature causes severe stresses in all three spans and in Piers 3 and 4. In the spans the stresses are increased from 72 to 92% of the allowable, and the bending stresses caused in the piers are from 21 to 143% of the allowable, assuming the piers to be of 600-lb. concrete. It is interesting to note that the stresses in the spans decrease as those in the piers increase.

TABLE 2.

Span.	Area, in square inches.	Average span, in inches.	Pier.	Assumed height, in inches.	I, in inches.^{4}	V, in inches.
6	14 300	600	5	480	509 201 000	230
5	13 960	536	4	480	752 342 100	275
4	13 960	480	3	480	1 090 534 000	327

If an expansion joint is placed at Pier 3, we have Case IV. The temperature stresses in Span 4 and Pier 3 are reduced to zero; those in Spans 5 and 6 are reduced; and the bending stresses in Piers 4 and 5, lacking the strong support of Pier 3, are increased, Pier 4 being stressed to 182% of the allowable.

If, instead of placing a joint at Pier 3 we place one at the abutment, the stresses in the spans are still further decreased, as are the bending stresses in Piers 3 and 4. Pier 5, however, takes a heavy increase in stress to 126% of the allowable unit stress in concrete.

If, in addition to a joint at the abutment, we place one at Pier 3, we have Case III, the most favorable arrangement of the five considered, the stress in Span 5 being only 27% of the allowable; but the stresses in the piers are still high, being 65 and 80% of the maximum allowable. They can be neglected, however, as the direct stress is small.

Case II produces a stress in Span 6 of 40% and in Pier 5 of 125% of the allowable unit stress.

The foregoing stresses, of course, will be modified somewhat by the fact that there must still be considerable resistance at the expansion joints, due to friction.

The problem is now resolved into one of determining the relative economy of expansion joints and of reducing the maximum live-load and dead-load unit stresses by increasing the section. Case III is the only arrangement with a restrained span which would not produce prohibitive stresses in at least one of the piers. It is also to be pointed out that increasing the section of Span 5 will increase the stresses in Piers 4 and 5 in direct proportion.

The plan finally adopted was to put expansion joints at the abutment and Pier 3 and a sliding joint over Pier 5. The combination spans of the east end of the viaduct are all provided with expansion joints.

Mr. I. L. Simmons and C. E. Smith, M. Am. Soc. C. E., were the Bridge Engineers, respectively, of the Chicago, Rock Island and Pacific, and the St. Louis, Iron Mountain and Southern Railroads responsible for the design of this bridge.

AMERICAN SOCIETY OF CIVIL ENGINEERS

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PAPERS AND DISCUSSIONS

This Society is not responsible for any statement made or opinion expressed in its publications.

CONCRETE-LINED OIL-STORAGE RESERVOIRS IN CALIFORNIA: CONSTRUCTION METHODS AND COST DATA

Discussion.*

By Ralph J. Reed, Assoc. M. Am. Soc. C. E.

Ralph J. Reed,† Assoc. M. Am. Soc. C. E. (by letter).—The remarkable growth of the petroleum oil industry in California during the past 15 years, shown in a most striking manner by the increase in annual production from 4 324 484 bbl. in 1900 to an estimated production of 103 000 000 bbl. in 1914, has resulted in the rapid development of facilities for handling and storing crude oils. By far the largest proportion of the crude oil stock of the State is stored in steel tanks, but there are in service, or ready for service, at the present time, 29 concrete-lined oil-storage reservoirs, having a total capacity of nearly 19 000 000 bbl. Reservoirs of this type are used largely for the storage of fuel oils varying in gravity from 14° to 18° Baumé. The lighter refining crudes, so far as the writer knows, are not stored in reservoirs, on account of the likelihood of large loss from the evaporation of the lighter and more valuable constituents, and on account of some uncertainty as to their effect on the concrete lining. Mr. Reed.

Some three or four years ago, when preparing to construct an oil reservoir, the writer had a search made in the Library of the Society for articles bearing on the subject. He was at that time unsuccessful in obtaining any information of value, and therefore welcomes Mr. Cole's paper, as it embodies a description of the latest practice in this type of construction.

It is the writer's opinion that the successful building of these reservoirs depends on a number of factors. Chief among these, as far as the earthwork is concerned, are the proper compacting of the material of the fill, and the careful building of the refill, both the

* Discussion on the paper by E. D. Cole, Assoc. M. Am. Soc. C. E., continued from January, 1916, *Proceedings*.

† Los Angeles, Cal.

Mr. Reed. bottom and the side slopes, so as to provide a uniform backing for the thin slab concrete lining. The "sheep's foot" or petrolithic rolling tamper is more successful than any other type of roller in building up a solid embankment, and the use of an ordinary road grader, to spread the material on the fill, and of a heavy disk harrow, to cut up clods of earth has proved helpful. The material of which the embankments of the reservoir at San Luis Obispo (referred to by Mr. Cole) are built, is a mixture of sand and heavy clay. The embankments built by the methods described appear to be nearly as well compacted as the ground on which they rest. The spreading of material in thin layers, and the use of as much water as possible without making the material too wet to work on, together with thorough tamping, have accomplished this result.

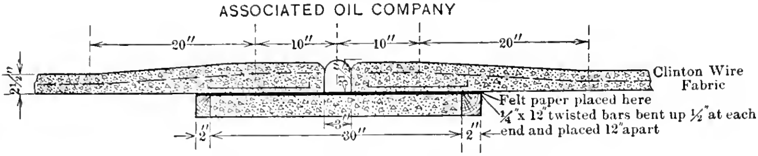
The method of trimming the excess material from the inner slopes, as developed by Messrs. Cole and Zeller, is extremely rapid and effective in bringing the inner slopes to line and grade with a minimum of hand work, to which it is so far superior, both in economy of labor and in results obtained, that it should be worthy of adoption on any similar earthwork where it is desired to finish a slope to accurate dimensions. In order to minimize the effects of erosion on the outer slopes of the embankment, the practice of sprinkling the outer edge of the fill for a width of 6 or 8 ft. with heavy crude oil has been followed. This is done with a tank wagon equipped with a sprinkler pipe, and is carried on during the building of the fill. The oil tends to bind together the particles of material on the outer edge of the fill, and rainfall has little serious effect. Squirrels and gophers apparently dislike to burrow in oil-saturated soil, and thus the attacks of these rodents on the embankment are prevented.

It is believed to be easier and safer to erect the roof posts and girders from the floor with a derrick resting on the floor, than with a hand derrick from the fill or from the completed portion of the roof, as described by Mr. Cole. The small saw, driven either by an electric motor or a small gasoline engine, is a labor saver, when it is considered that about 220 000 ft. b. m. of sheathing, in 8 to 16-ft. lengths, must be laid, and that the number of sawn joints is large. The writer believes that Mr. Cole's statement regarding the erection of the roof by a force of 50 men in 7 days refers only to the erection of the posts, girders and rafters, which, in a reservoir of this size, would amount to about 300 000 ft. b. m. The force named would hardly be able to complete the entire roof in the time specified.

The erection of the roof prior to the pouring of the concrete lining is believed to be good practice and of importance, as it allows better control of the setting of the lining. Temperature changes are relatively small, and the lining, when carefully placed, shows little tendency even to small checks. Inspection of a recently completed reservoir, 18 days after pouring, showed practically no cracks in the bottom and about a dozen hair cracks on the entire slope. These were approximately at right angles to the intersection of the slope with the reservoir bottom, and extended up the slope from 5 to 15 ft. The writer has followed, with success, the Fuller-Thompson method of proportioning concrete, by mechanical analysis of the aggregates and construction of the curves to approximate the ideal curve, but he would use nothing larger than ¾-in. material in the mix for the floor, with ½ to ⅝-in. material for the side slopes. Mr. Reed.

Pouring the concrete lining on a 1:1 slope without forms, as Mr. Cole states, is not difficult, provided the earthen embankment has been well built, and shows no tendency to break down. The writer, however, would recommend the 1:1 inside slope only where the material to be handled contains a large percentage of clay. For embankments of sandy materials he would hesitate to recommend the 1:1 slope, but would prefer 1½:1.

EXPANSION JOINT
USED ON 750 000-BARREL RESERVOIR OF
ASSOCIATED OIL COMPANY



NOTE:
Metal sheet to be formed on the job from one continuous sheet of No.20 Galvanized Iron 28″ wide and 40′ long. Edges of sheet to be slit ½″ deep every 3″ longitudinally, and bent in opposite directions.

FIG. 15.

Expansion joints, of the type shown by Fig. 15, were used in the earlier reservoirs. They were constructed with a sheet of No. 20 gauge galvanized iron bent to the form shown, continuing from top to bottom of the reservoir, and placed so as to connect successive slabs of the concrete lining of the slope. In later reservoirs they have been omitted entirely, as they were in the case of the reservoir just referred to, which showed only twelve small cracks. It is the writer's belief that expansion joints are not necessary in work of this type, provided there is sufficient reinforcement in the slab and the concrete is carefully cured. Temperature variations are unusually small, especially when the reservoir is in service. Temperature observations in an empty reservoir for a short period are given in Table 1. The temperature of the oil in storage varies, during a period of one year, throughout a range of about 20°, the average temperature of oil in storage at San Luis Obispo being 60° Fahr.

The joint between the bottom and slope of reservoirs of this type has usually been constructed as shown in the illustrations accompany-

Mr. Reed. ing Mr. Cole's paper. This is not designed as an expansion joint, as the reinforcing is carried through from slope to bottom, but it forms a convenient line to which to pour. As the writer believes that the small wooden form, of L cross-section, does not need to be left in place, he removes it before pouring the slope concrete.

TABLE 1.—TEMPERATURES, IN DEGREES FAHRENHEIT, WITHIN AND WITHOUT RESERVOIR NO. 6 AT SAN LUIS OBISPO, CAL. (RESERVOIR EMPTY.)

December, 1915.	AT CENTER.			AT SLOPE.			OUTSIDE.		
	8.00 A. M.	12.00 M.	4.00 P. M.	8.00 A. M.	12.00 M.	4.00 P. M.	8.00 A. M.	12.00 M.	4.00 P. M.
2	62	62	66	62	62	66	60	70	64
3	60	62	62	60	62	62	58	62	68
4	58	60	64	58	60	64	50	54	56
6	54	62	66	54	62	66	46	68	62
7	56	62	67	56	62	67	44	71	60
8	55	63	64	55	63	64	42	55	53
9	59	61	64	59	61	64	49	60	54
10	52	63	62	52	63	62	39	62	52
11	51	58	63	51	58	63	44	60	55
13	58	61	64	58	61	64	52	63	56
Average.........	56.5	61.4	64.2	56.5	61.4	64.2	48.4	62.5	58.0
Daily average...	60.7			60.7			56.3		

With reference to the swing pipes on the inner ends of the outlets, it may be said that these are commonly used both in oil-storage tanks and in reservoirs. They allow the removal of oil from any level, and avoid the withdrawal with the oil of any water which may have collected at the bottom of the reservoir. They are incidentally of use when repairs are to be made to the controlling gate-valves.

The writer is inclined to agree with the statement of Mr. Bowie, that coverings of asphalt-saturated felt—the so-called roofing "paper"—are not satisfactory for the roofs of tanks used for the storage of the lighter refining oils. He does not find them unsatisfactory for the covering of tanks (or reservoirs) for the storage of fuel crudes or residua, though he admits that they are not usually gas-tight. For steel tankage, the $\frac{1}{8}$-in. steel-plate roof makes an excellent gas-tight covering, when the container is to be used for light refining crude oil, though, in his opinion, caulking the bevel-sheared edges of the plates is preferable to the insertion of a thread gasket saturated with red lead between the laps of the sheets. As was stated earlier in the discussion, few, if any, concrete-lined reservoirs are used for the storage of oils having volatile constitutents which are as valuable as those assumed by Mr. Bowie in his computation of the loss from evaporation.

AMERICAN SOCIETY OF CIVIL ENGINEERS

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PAPERS AND DISCUSSIONS

A STUDY OF THE DEPTH OF ANNUAL EVAPORATION FROM LAKE CONCHOS, MEXICO

Discussion.*

By Messrs. Adolph F. Meyer and H. Hawgood.

Adolph F. Meyer,† M. Am. Soc. C. E. (by letter).—The writer has read this paper with much interest, and, in this discussion, does not desire to dispute the validity of the authors' principal conclusion, relating to the annual evaporation from Lake Conchos. He does, however, desire to present data which appear to disprove the subsidiary conclusion regarding the relation between evaporation depth and elevation above sea level. Inasmuch as the data on which the primary conclusion is based include Piche evaporimeter observations in Texas and New Mexico in 1887-88, the writer's discussion regarding the subsidiary conclusion also has some bearing, at least, on the method of arriving at the primary conclusion. Mr. Meyer.

The authors state,‡ regarding the relation between evaporation depth and elevation above sea level:

> "(*e*)—In the Great Plateau Region, and at elevations above sea level of 600 to 5 000 ft. and monthly mean temperatures higher than 70° Fahr., the increases in the evaporation depth at any given mean temperature are directly proportional to increases in elevation; but at monthly mean temperatures lower than 70° Fahr., and at the lower elevations, the evaporation depth at any given mean temperature increases with the increase in elevation, but less rapidly than in direct proportion."

These conclusions are further presented in Diagrams (*a*) and (*b*) of Fig. 4. Although the line of zero evaporation is not given in

* Discussion of the paper by Edwin Duryea, Jr., M. Am. Soc. C. E., and H. L. Haehl, Assoc. M. Am. Soc. C. E., continued from January, 1916, *Proceedings*.

† Minneapolis, Minn.

‡ *Proceedings*, Am. Soc. C. E., September, 1915, p. 1733.

Mr. Meyer.

Diagram (*a*), one is at once impressed with the fact that, according to this diagram, there would appear to be no evaporation on the Great Plateau at an elevation of about 3 000 to 4 000 ft. when the monthly mean temperature reached 30° Fahr., and at an elevation of about 2 000 to 2 500 ft., when the monthly mean temperature reached 40°, and that at elevations of less than 1 000 ft., there would appear to be no evaporation at monthly mean temperatures below about 45 degrees.

As to the applicability of the authors' conclusions regarding the relation of evaporation to elevation, the following statements* appear in the paper:

"Also, it is believed that for places within the limits of the Great Plateau, from Mexico on the south to perhaps Colorado and Utah on the north, fair general approximations to local monthly and yearly evaporation depths may be read directly from Fig. 4 without other data than local mean temperatures and elevations.

* * * * * * *

"Since, at elevations above sea level, water boils at temperatures below 212° Fahr., it appears at least reasonable that at any given temperature water will vaporize or evaporate more quickly at high than at low elevations.

"On Diagram I of Fig. 13 are plotted the curves showing the relations between temperature and evaporation in 3-ft. square floating-pans at five measured evaporation stations on the Great Plateau. On each curve is marked the name and elevation of its station; and this diagram shows in a general way that at equal mean monthly temperatures the evaporation depth is greater at stations of higher elevation. The combined diagram of the Piche evaporimeter observations (Plate XXXII) also shows this in a general way.

* * * * * * *

"In the study made for Fig. 4, the values of Table 24 were extended upward to Elevation 7 000 ft., downward to 500 ft. below sea level (say as for Salton Sea and Dead Sea), and to the 2-in. increment of 16 to 18 in. monthly evaporation depth; and the values of Table 23 were extended to the same limits. This was done because it was surmised that the combined influence on evaporation depth of all other conditions except temperature and elevation might be relatively unimportant—perhaps so small as to permit the estimation of approximate evaporation losses directly from Fig. 4, not only for places on the Great Plateau, but even generally throughout the United States.

"However, the diagram of the extended Table 23 showed serious contradictions beyond 12 in. monthly evaporation (*e. g.,* at 400 ft. below sea level and 81.4° mean monthly temperature, the 6 and 18-in. lines intersect and give either 6 or 18 in. monthly evaporation), and hence it shows that values derived by extensions so far beyond the observed limits are very unreliable.

"Also, comparisons were made of the evaporation losses shown by such extended Fig. 4, with the observed evaporations at Salton Sea

* *Proceedings,* Am. Soc. C. E., September, 1915, pp. 1740, 1767-1768.

(263 ft. below sea level), Lake Tahoe (6 225 ft. elevation), and Coyote or Laguna Seca (240 ft. elevation)—all in California and outside the limits of the Great Plateau—and all such comparisons showed very serious disagreements, and indicated that Tables 23, 24, and 25, and Fig. 4 are not applicable with safety to places outside the limits of the Great Plateau." Mr. Meyer.

In view of the fact that the authors believe that "for places within the limits of the Great Plateau, from Mexico on the south to perhaps Colorado and Utah on the north, fair general approximations to local monthly and yearly evaporation depths may be read directly from Fig. 4 without other data than local mean temperatures and elevations," notwithstanding the fact that extensions of Fig. 4 showed serious contradictions, and that comparisons of observed evaporation losses at Salton Sea, Lake Tahoe, and Laguna Seca, with values determined from such extended Fig. 4, showed very serious disagreements, and that elevation *per se* affects evaporation, "since, at elevations above sea level, water boils at temperatures below 212° Fahr.", further discussion of this subject would not appear to be amiss.

Piche Evaporimeter Observations.—In Table 17, and on Plate XXXII, the authors present Piche evaporimeter records for eleven stations in Texas and New Mexico; and, in referring to the Piche evaporimeter records which are presented as substantiating their subsidiary conclusion regarding the relation between evaporation and elevation, they state:

"These evaporimeter records* are stated to have been published in the *Monthly Weather Review* of the U. S. Signal Service, September, 1888, p. 235, and to have been records of observations made in the year, July, 1887–June, 1888."

Apparently, then, the authors did not examine the original source of these data.

Reference to the *Monthly Weather Review* of September, 1888, discloses the following facts, which are of interest in connection with the authors' use of the Piche records:

"The Piche evaporometer [evaporimeter] consists of a glass tube 9 inches long and 0.4 of an inch internal diameter. The top end is closed and has an eye for suspending the instrument. The tube is filled with water and on the open end a paper disk 1.2 of an inch in diameter is placed and held in position by a brass fixture sliding easily in a collar along the tube. Water is supplied to the paper from the tube by capillary action, and evaporates freely from it into the air, the amount depending on the dryness of the air and the velocity of the wind. There is a scale etched on the tube to cubic centimeters and tenths. The difference in the readings of the top of the column of water gives the volume evaporated from the paper in the interval between the readings."

* "Public Water Supplies", Turneaure and Russell (1911), Second Edition, p. 60.

Mr. Meyer. These instruments were standardized so as to give comparable readings. It was found by experiment that the height of water in the tube made no appreciable difference in the rate of evaporation. It was found by Dr. Riegler, in 1879, that the thickness of the paper did not affect the evaporation more than might be expected from the difference in effective area, as represented by the relative areas of the edge of thin paper and of thick blotting paper. The same conclusion was reached by Professor Russell in his investigation.

According to this article in the *Monthly Weather Review,* which, by the way, was written by T. Russell, Assistant Professor, Signal Service:

"These instruments [referring to the Piches] were mounted in the thermometer shelters at the stations. They were read once a day at 10 P. M. during June, and at 8 P. M. during July, August, and September. The difference in the readings on successive days gave the amount of evaporation for the various days.

"The shelters on Signal Service stations are usually at a height of nine feet above the roof of building where situated. * * *

"To determine the relation between the evaporation from a water surface and that from the Piche, two Piches were compared, in the quiet air of a closed room, with two tin dish-evaporimeters, each 6.55 centimeters in diameter and 1.3 in depth. * * *

"The results of the experiments showed that the rate of evaporation from the dishes diminished regularly as its water surface fell below the edge of the vessel. The Piches evaporated 1.33 times that of the dishes, surface for surface, as compared with the dishes while quite full. The coefficient increased to 2.05 as the surface of the water in the dish fell.

"The coefficient used to reduce the Piche evaporations on stations to an equivalent water surface was 1.33."

Russell's Evaporation Table.—Russell's table giving "Depth of evaporation, in inches, at Signal Service stations, in thermometer shelters, computed from the means of the tri-daily determinations of dew-point and wet-bulb observations", first published in the September, 1888, *Monthly Weather Review,* and reprinted in Turneaure and Russell's book on "Public Water Supplies", and in a number of other publications, is based on the depth of evaporation, in inches, observed with Piche instruments, during June, 1888, at the stations shown in Table 65.

The evaporation at the 140 stations, given in Russell's table previously referred to, and from which the data used by Messrs. Duryea and Haehl were taken, does not represent Piche evaporimeter observations at the various stations for 12 months, but merely the computed evaporation determined by a formula derived from Piche observations for the single month of June, 1888, at the 18 stations listed in Table 65.

In deriving this formula, it was assumed, in the first place, that the evaporation observed with a Piche evaporimeter is 1.33 times that from a water surface. It was further assumed that, even though there was considerable variation in the observed wind velocity during June, 1888, and that, although at a wind velocity of 5 miles per hour, the evaporation from a Piche was found to be 2.2 times that from one in quiet air, at 10 miles 3.8 times, and at 15 miles 4.9 times, the effect of the wind could be neglected in the derivation of the formula. The wind velocity measured by an anemometer set up inside of the shelter at Washington City, for 8 days, gave a wind velocity of 3.48 miles an hour, as compared with a velocity of 6.63 miles outside, or only 52% of the velocity outside. Mr. Meyer.

TABLE 65.

Station.	Temperature, in degrees Fahrenheit.	Evaporation depth, in inches.	Percentage of relative humidity.	Wind velocity, in miles per hour.	Barometer, in inches Hg.
Boston	66.8	5.16	65.0	10.2	29.8
New York	71.4	4.49	67.6	8.3	29.7
Washington	73.0	4.64	68.0	4.8	29.8
Cincinnati	74.2	6.22	56.6	6.1	29.3
Memphis	75.4	4.33	70.8	4.8	29.6
New Orleans	77.3	3.82	77.7	6.8	29.9
Chicago	67.4	5.59	64.1	10.3	29.2
St. Louis	73.2	6.18	68.5	9.7	29.3
Keeler	73.9	11.66	23.0	7.9	26.2
Yuma	85.6	13.87	25.3	7.3	29.6
El Paso	83.0	13.91	24.1	8.2	26.1
Dodge City	74.5	7.80	53.0	11.6	27.3
San Antonio	78.0	2.76	75.3	8.1	29.1
Omaha	70.0	7.01	63.2	7.6	28.7
Denver	68.4	9.42	31.4	8.0	24.7
St. Vincent	62.8	5.63	69.5	7.6	28.9
Helena	58.8	4.88	56.6	7.9	25.7
Boise City	64.2	5.83	48.8	3.1	27.0

In deriving the formula, the observed evaporation was first reduced on the basis of the observed barometric pressure, on the assumption that the evaporation varies inversely as the barometric pressure, that is, the observed evaporation at Denver, for example, where the barometer read 24.7 in., was assumed to be $\frac{30.0}{24.7}$, or 1.21 times the theoretical evaporation used in determining the other members of the equation. In other words, the tabular values for evaporation depth, based on the Piche measurements used by Messrs. Duryea and Haehl in Table 17, and on Plate XXXII, had already been corrected for elevation on the assumption that evaporation varies inversely as the barometric pressure.

Mr. Meyer. From the observed evaporation for June, 1888, the following formula was derived by Russell:

$$\text{Evaporation (in inches per month)} = 30\left(\frac{A\,p_w\,B\,(p_w - p_d)}{b}\right),$$

where

p_w = Vapor tension, in inches of mercury, corresponding to monthly mean wet-bulb temperature;

p_d = Vapor tension, in inches of mercury, corresponding to monthly mean dew-point temperature;

b = Mean barometric pressure, in inches of mercury;

$A = 1.96$;

and $B = 43.88$.

The values for A and B were derived from the observations for June, 1888, at the 18 stations listed in Table 65, by the method of least squares.

It is interesting to note the differences between the computed and observed evaporation for June, 1888, at two of the stations used by Messrs. Duryea and Haehl. At El Paso, Tex., the evaporation observed by the Piche evaporimeter, in June, 1888, was 13.91 in.; the computed evaporation was 13.6 in. At San Antonio the observed evaporation was 2.76 in.; the computed evaporation was 4.5 in.

In comparing evaporation from a Piche with evaporation from a reservoir, it is necessary to take account of the fact, stated by Russell in the *Monthly Weather Review*,* that:

"In the case of the Piche evaporometer the temperature of the evaporating water is strictly that of a wet-bulb thermometer exposed at the same place."

The Piche evaporimeter observations represent the evaporation at an average wind velocity, at the instrument, of approximately 3½ miles per hour. On the other hand, as stated by Russell:

"The effect of the high exposure of the shelters is to make the figures too great, the wind action being far greater at the height of the shelters than at the level of the ground. The evaporation taking place from a small paper disk, as in the results obtained with the Piche instrument, have a tendency to be too small, as the determining temperature of evaporation is that of a wet-bulb thermometer exposed under similar circumstances. In the case of a body of water the determining temperature of evaporation is nearly that of the average temperature of the air."

All the data used by Messrs. Duryea and Haehl on Plate XXXII are of no value whatever, in so far as efforts to show a relationship between evaporation and elevation are concerned, because, in the first place, they are based on an assumed variation of evaporation with

* September, 1888, p. 237.

elevation in the ratio of 30 divided by the barometric pressure, and, in the second place, all remaining differences in evaporation are directly attributable to changes in temperature and relative humidity. The evaporation at El Paso for June, 1888, is based on a relative humidity of practically 25%, and the evaporation at San Antonio on a relative humidity of practically 75 per cent. It must be apparent, then, that the computed evaporation at the 11 Weather Bureau stations, used by Messrs. Duryea and Haehl on Plate XXXII and in Table 17, cannot be used to determine the effect of elevation on evaporation, or even to substantiate a conclusion arrived at in another way. Mr. Meyer.

Piche Evaporimeter Observations not in Agreement with the Authors' Deductions.—In order to show, further, that Russell's evaporation tables indicate no relationship between elevation and evaporation, and to show the differences in monthly evaporation as given by Russell and as determined from Fig. 4, a study has been made of Russell's values for the stations (situated on or near the Great Plateau) given in Table 66.

TABLE 66.

Station.	Approximate elevation above sea level, in feet.	Percentage of mean annual relative humidity (1887-1888).
Yuma, Ariz.	140	48
Keeler, Cal.	3 600	38
Winnemucca, Nev.	4 350	46*
Salt Lake City, Utah	4 350	52
Denver, Colo.	5 300	52
Prescott, Ariz.	5 400	64

* The relative humidity at Winnemucca varied from 24.4% in August, 1887, to 83.4% in June, 1888. At all other stations the variation during the year was considerably less.

The monthly evaporation, according to Russell, at each of the stations listed in Table 66, is shown in Figs. 23, 24, and 25, together with a curve representing the average relationship between evaporation and temperature for each station. There is also shown, on each diagram, the relation between evaporation and temperature, as determined from Diagram (*a*) of Fig. 4, in order to indicate the lack of agreement between the conclusion reached by Messrs. Duryea and Haehl, with respect to the relation between evaporation and elevation, and Russell's evaporation values at other stations on or near the Great Plateau.

It will be noted that the writer has used a curve instead of a straight line for the purpose of better showing the relation between temperature and evaporation. In fact, this relation could be shown still better if separate curves were drawn for evaporation during the

Mr. Meyer.

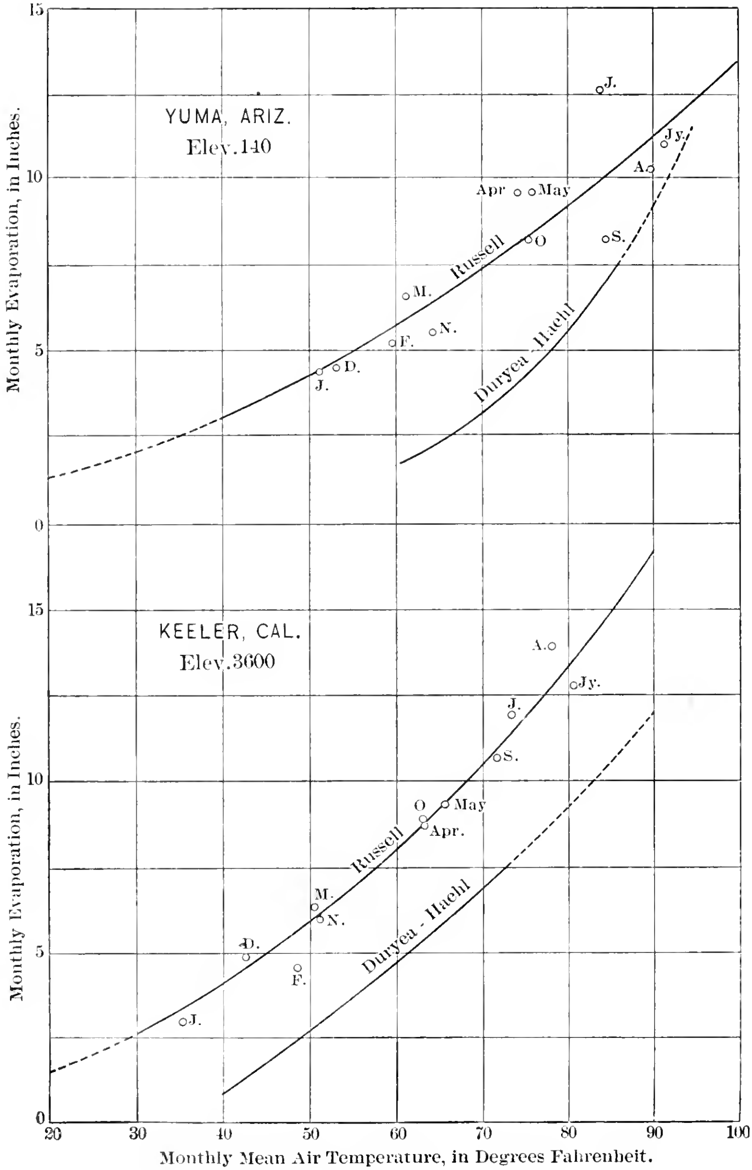


FIG. 23.

Mr. Meyer.

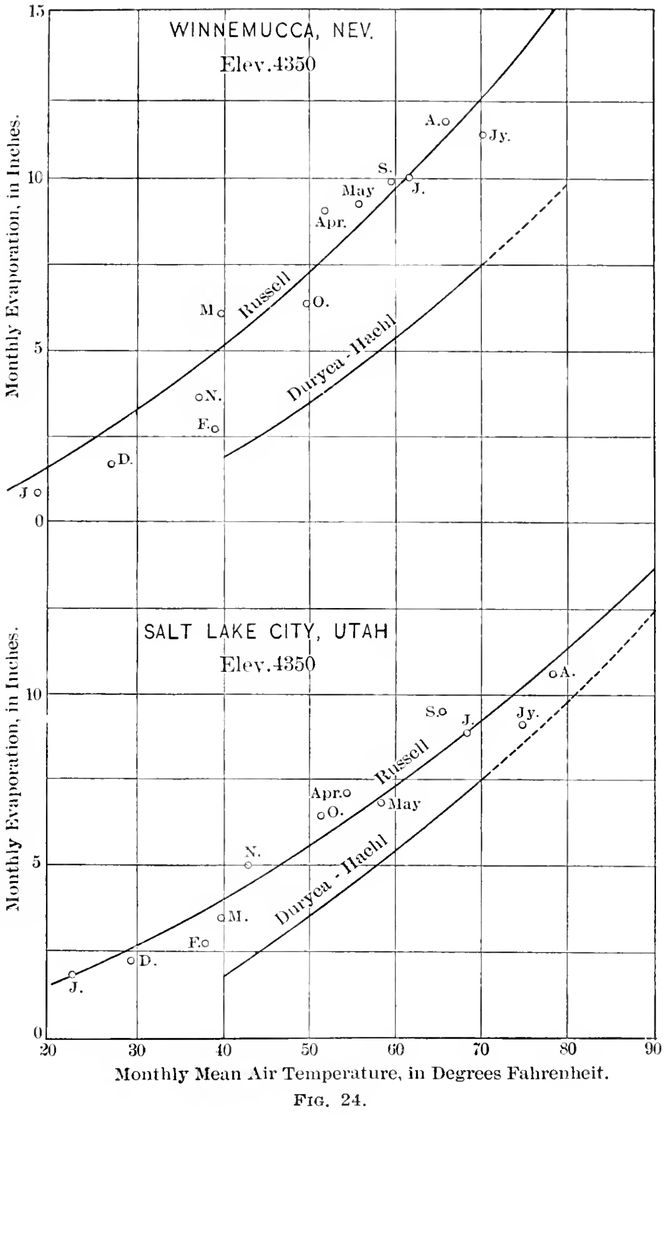


Fig. 24.

Mr. Meyer.

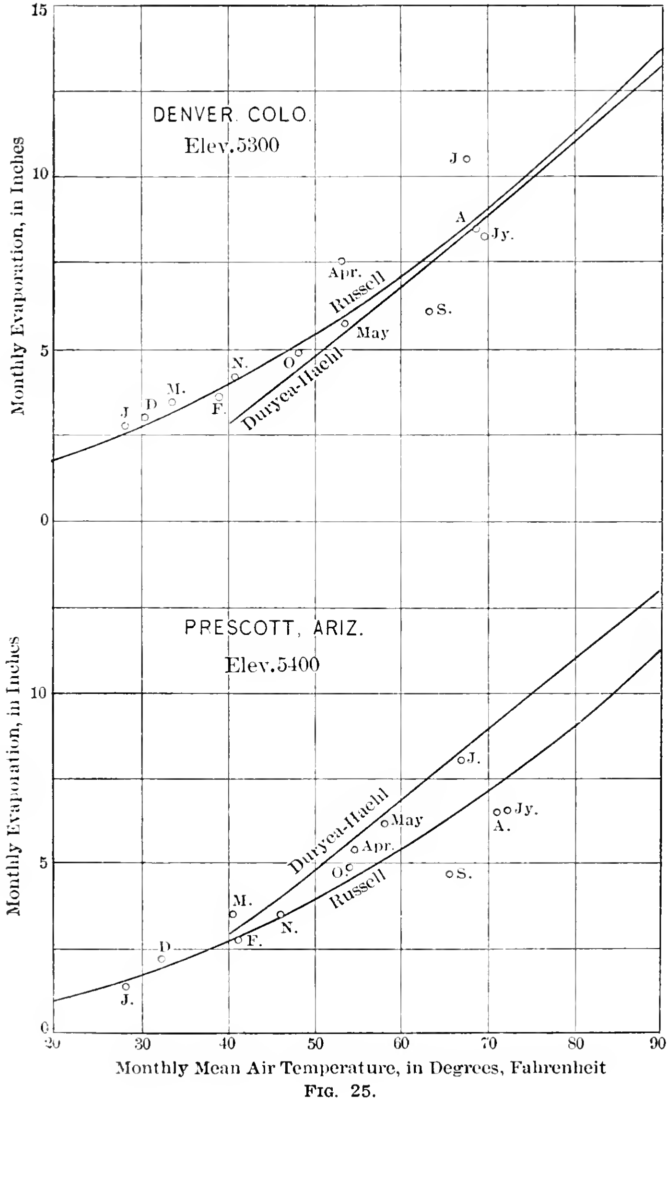


FIG. 25.

spring and during the fall, in accordance with the method adopted by the writer in his paper "Computing Run-off from Rainfall and Other Physical Data".* Mr. Meyer.

The curves for the six stations are shown collectively in Fig. 26, in order to indicate the lack of relationship between evaporation and elevation. The differences are accounted for by differences in relative humidity. If relative humidity were a function of elevation, the

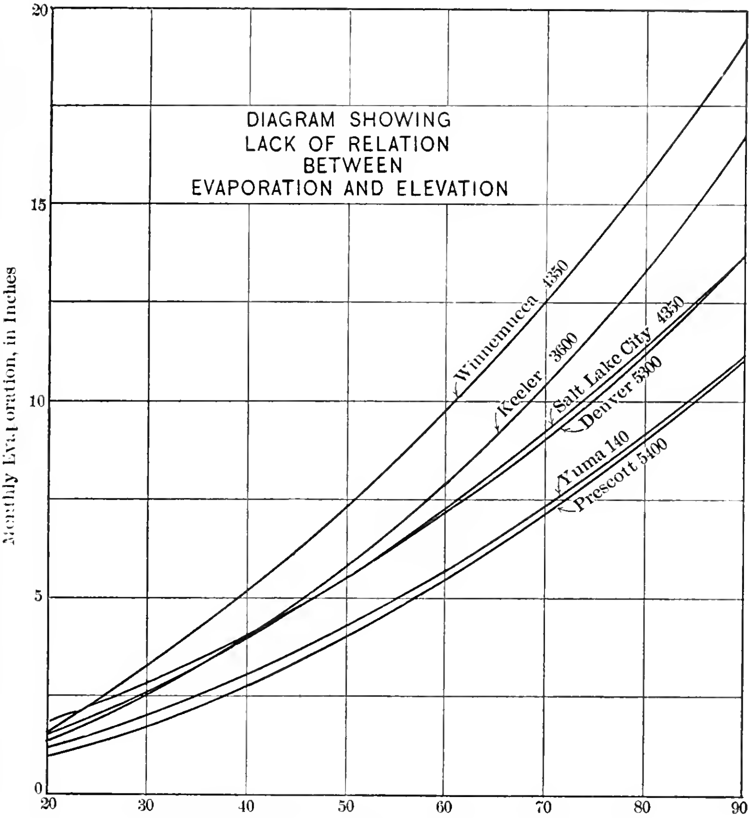


Fig. 26.

deductions of Messrs. Duryea and Haehl might be valid, but the data presented by the writer indicate that the relationship is merely incidental, and at best too uncertain to afford a rational basis for estimating evaporation.

If the authors' conclusions are limited in application to localities possessing similar climatic characteristics, then surely one would

* *Transactions*, Am. Soc. C. E., Vol. LXXIX, p. 1056.

Mr. Meyer. look for at least some reference to climatic characteristics of the region under discussion, aside from mere records of temperature, that is, one would expect to find some record of relative humidity, wind velocity and direction, sunshine, etc. If the conclusions presented in Fig. 4 are to be of service at all, they must be applicable at least to points on the Great Plateau, as indicated by the title. The result of a comparison of the conclusions of Fig. 4 with Russell's evaporation tables fails to give confidence in the validity of those conclusions.

Further data could readily be adduced from Russell's evaporation tables to show that, whatever effect elevation has on evaporation, it is merely incidental, and dependent on the reduction of relative humidity with increase in elevation. Even in the Great Plateau Region, however, there are many stations of low elevation at which the relative humidity is high, resulting in just the opposite relation between elevation and evaporation from that pointed out by Messrs. Duryea and Haehl. Pikes Peak, for example, has an elevation of more than 14 000 ft., yet the observed relative humidity is about 75%, as compared with a relative humidity of about 40% at Fort Grant, Ariz., with an elevation of 4 900 ft.

In passing, it may be remarked that Professor Bigelow's formula, quoted by Messrs. Duryea and Haehl, takes no cognizance of elevation as a factor in governing evaporation. Judging from extensive quotations from Professor Bigelow's writings, one is led to conclude that the authors have given weight to Bigelow's work; yet, on the other hand, it is difficult to see why they disregard completely the fact that Bigelow's formula does not contain elevation as a factor.

Relation between Evaporation and Elevation as Determined from Pan Measurements.—From the preceding discussion it is evident that the Piche evaporimeter records show no such relationship between elevation and evaporation as presented by the authors in Figs. 4 and 13.

As previously indicated, if relative humidity were a function of elevation, then elevation above sea level would be as good a measure of evaporation as relative humidity, but such a relationship between relative humidity and elevation does not exist, except as an accidental relation on portions of the Great Plateau, where regions of low precipitation are also regions of high elevation.

The foot-note to Diagram II of Fig. 13 indicates that the authors considered the records at El Paso, Tex., as unreliable, in so far as their use in determining the relation between elevation and evaporation was concerned, even though, in the discussion of the pan measurements, they state:

"Because of its comparative nearness, that at Elephant Butte is perhaps the most important (next to that at El Paso) of any of the Texas and New Mexico evaporation records available for the determination of the probable evaporation at Lake Conchos."

Mr. Meyer.

It is interesting to note, however, that the reason the El Paso records do not conform to the authors' deduction regarding the effect of elevation on evaporation is because of variations in relative humidity. This is shown by a comparison of the observed relative humidity at El Paso for the period covered by evaporation measurements, with the relative humidity observed at Santa Fé, N. Mex., a short distance north of Albuquerque. These records indicate that the average relative humidity during the summer months of 1889, 1890, and 1892, with temperatures of from 75 to 80°, is 31%, whereas the average relative humidity at Santa Fé, during the summer months of 1900 and 1903, for temperatures of from 75 to 80°, is 42 per cent. On the other hand, the relative humidity at El Paso, during November, December, January, and February, for temperatures of from 45 to 50°, is 45%, and the relative humidity at Santa Fé, during the winter months, when the temperature ranged between 40 and 50°, is 41 per cent. That is to say, the reason that the lines for El Paso and Albuquerque, in Diagram I of Fig. 13, cross each other is apparently because the relative humidity at high temperatures is less at El Paso, and consequently the evaporation greater, than at Albuquerque, and at low temperatures the relative humidity at El Paso is greater, and consequently the evaporation less than at Albuquerque. Moreover, the records indicate relatively uniform wind velocity at El Paso during the two periods under consideration, whereas those for Santa Fé indicate a somewhat higher wind velocity during the winter months. There appears to be good reason, then, for believing that the El Paso records do not conform to the authors' lines of Diagram II of Fig. 13 because the relative humidity at El Paso is exceptionally low, rather than because the evaporation observations at El Paso covered only portions of a month. Where deductions are properly made, it is believed that evaporation data covering 20 days are practically as good as those covering 30 days, although, when averaging results, less weight should be given to the average of 20 days' records than to that of a full month. An error sometimes made, however, and which is of consequence, is that of plotting the evaporation for 15 or 20 days out of a month against the monthly mean temperature instead of against the mean temperature for the portion of the month over which the records extend.

It is interesting to note, further, that the general relationship pointed out by the authors in Fig. 13, between evaporation and the elevation of Austin, Carlsbad, Elephant Butte, Albuquerque, and El Paso, is to be expected from the differences in relative humidity at these or near-by stations. The relative humidity at Austin, Tex., should be about 68%, which is the relative humidity of San Antonio. A reasonable value for Carlsbad would appear to be 58%, on the

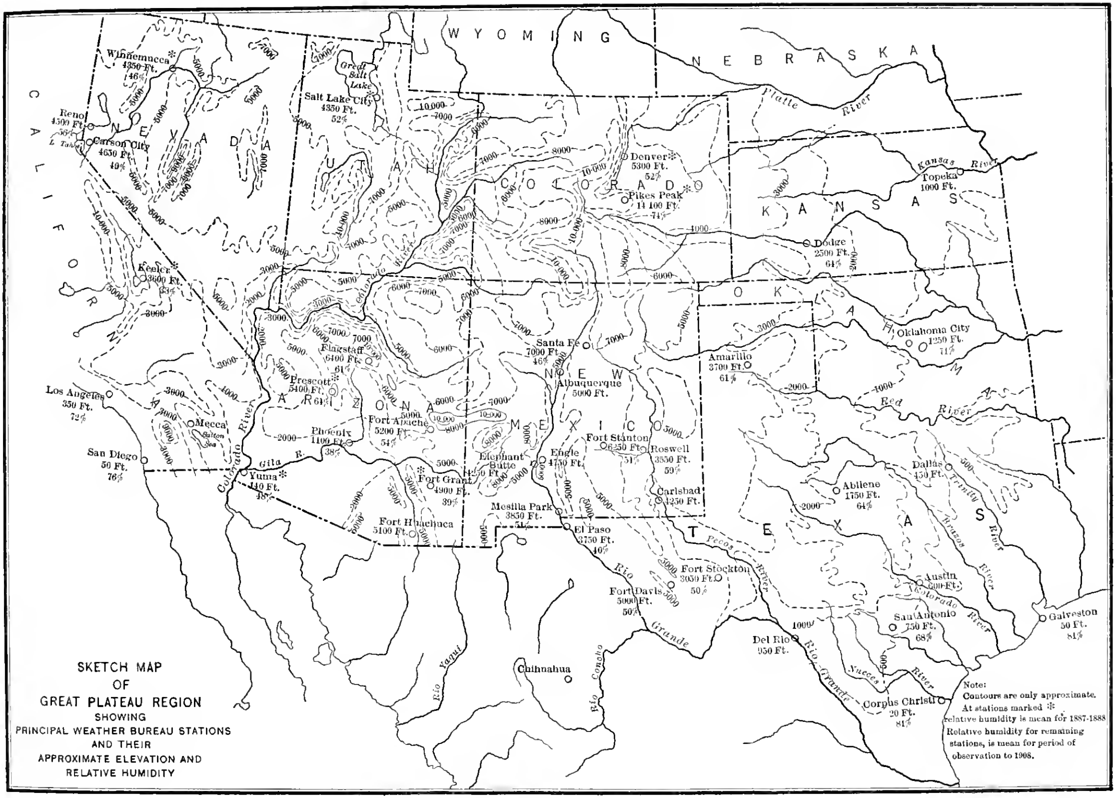
Mr. Meyer. basis of 56% at Fort Stockton and 59% at Roswell. Elephant Butte might be expected to have a relative humidity of about 50%, on the basis of 51% at Mesilla Park and 51% at Fort Stanton. The relative humidity for Albuquerque should be about 44%, on the basis of the records for Santa Fé during 1900 and 1903, which give 44% for that station. The relative humidity for El Paso, for the period covered by the records presented by the authors, was 36%, the normal relative humidity being 40 per cent. The location of these and other stations on or near the Great Plateau, is shown on the map, Plate III, which also gives very approximate contours for the region for which evaporation data are discussed in the paper.

In conclusion, the writer desires to state that he believes records of relative humidity and wind velocity, combined with records of temperature, afford a far more accurate and reliable basis for estimating evaporation from reservoirs than Fig. 4. Sling psychrometer measurements of relative humidity are easily made. By combining pan evaporation observations with observations of temperature, relative humidity, and wind velocity for even 6 months, reasonably good estimates of evaporation from reservoir surfaces can be made by a proper analysis and comparison of these data with long-term records at near-by stations.

The monthly mean relative humidity, particularly at continental stations, as indicated in the writer's Fig. 4* of his paper "Computing Run-off from Rainfall and Other Physical Data", shows a quite definite variation from season to season. By comparison of observed values covering a portion of the year with similar values at a near-by long-term station, a reasonably accurate curve of variation in relative humidity for the whole year can be drawn. These values of relative humidity can then be used in connection with monthly mean temperatures and wind velocity, determined in a similar way, for the purpose of estimating monthly evaporation. This method of comparison between short-term and long-term records permits one to ascertain whether the year in which observations were made was an abnormal one, and thus avoid basing conclusions on the results of observations for a year, or a part year, which may represent either high, low, or intermediate values. Moreover, by this method of comparison, it is also possible to determine the evaporation which would result from a combination of meteorological phenomena favorable to very high evaporation losses. As the evaporation is almost certain to be high during a year of low stream flow, the necessity for considering exceptional rather than average values is apparent.

The writer desires to reiterate the statement previously made, that the criticism offered in this discussion does not apply to the authors'

* *Transactions*, Am. Soc. C. E., Vol. LXXIX, 1915, p. 1068.



SKETCH MAP OF GREAT PLATEAU REGION SHOWING PRINCIPAL WEATHER BUREAU STATIONS AND THEIR APPROXIMATE ELEVATION AND RELATIVE HUMIDITY

principal conclusion, but merely to their subsidiary conclusion relating to the effect of elevation upon evaporation, and the suggested use of Fig. 4. Mr. Meyer.

The intent of this discussion is not to find fault with the authors' analysis of the available data leading up to the estimate of the mean annual depth of evaporation from Lake Conchos, but rather to supplement their discussion of the relation between evaporation and elevation by pointing out that such a relationship is not fundamental, but merely incidental, and therefore true over such restricted areas as to make elevation an unsatisfactory and unreliable index of evaporation, even for large portions of the Great Plateau Region, and a totally inapplicable one elsewhere.

H. Hawgood,* M. Am. Soc. C. E. (by letter).—Messrs. Duryea and Haehl have rendered a service of great value in adding to the knowledge of a subject about which opinions are more common than recorded facts. Nothing could more strongly emphasize the present wide divergency of views than the statement made in the paper that two prominent engineers judging of probable annual evaporation losses gave opinions 151% apart. Nor are such divergencies of opinion by any means uncommon. Obviously, it is a field where there is need of a greater knowledge of facts. The paper is replete with information, and its conclusions are logical. Mr. Hawgood.

Measurement of evaporation from pans can be carried out with any desired degree of detail and accuracy. The difficulty lies in connecting such measurements with the actual evaporation from an expanse of water, such as a lake or reservoir. The opportunities for doing this are few, the difficulties many, and the results, by reason of the numerous uncertain elements, can never be considered as absolute, except perhaps in the case of comparatively small lined reservoirs. Seepage will always confuse the results. The perfectly watertight reservoir site is probably non-existent in Nature; otherwise springs would be rarities. In striking a balance between inflow and outgo, losses by inevitable seepage become charged to evaporation.

Again, the ratio of the area of the evaporating appliances to that of the reservoir is usually very small, too small for results to be accepted without some reservation. It is not to be expected that two or more pans, together presenting an area of a few square feet, could represent with precision areas frequently, as in the case of Lake Conchos, several million times greater, with all their variations of depths and exposures. The authors meet this question fairly by considering their results and conclusions as a reasonable basis for reliable estimations.

There is need of a series of comparative experiments with pans of the usual depth of 18 in. and others of several feet in depth, with

* Los Angeles, Cal.

Mr. Hawgood.

a view of determining the depth of pan associated with least evaporation, a condition which would most closely represent evaporation from a free water surface. The pan is supposed to represent the top of a column of water extending downward to the bottom of the reservoir, with all its fluctuations of temperature. Shallow pans probably give too high evaporative values.

The manner of construction and finish of the pans also needs investigation; that they exert a marked influence on evaporation has been known for a long time. It was the subject of experiments by Mr. Baldwin Latham some 34 years ago.* For the convenience of members, the following quotation is made, prefaced by the remark that Mr. Latham first used a pan supported by an outside contact ring, and that when the sun shone on the evaporator greater evaporation occurred by reason of the water creeping up the side of the vessel by capillary action, where it was speedily evaporated. He then substituted an evaporator supported by a floating ring separated from the vessel itself, the type used to-day.

"At once there was a large reduction in the amount of evaporation. The film of water now extended up the sides of the vessel both on the outside as well as the inside, and so they were kept cool. He, however, carried the experiment still further on a number of evaporators painted different colours. He observed that from a painted gauge, even if black, there was a less amount of evaporation than from a plain copper gauge. That was because capillary action was more energetic in the metal gauge than in the painted gauges. In order to test the matter, he took three evaporators made of copper, each 5 inches in diameter, and holding at least 1 foot depth of water. One of these he had slightly greased inside, and that and another copper evaporator were allowed to stand in a tank of water immersed to within 2½ inches of the top, while at the same time the third evaporator was freely exposed to the atmosphere. The evaporation from these gauges in the month of May, 1882, when compared with that of the floating gauge 12 inches in diameter, and a gauge painted white, but immersed in water were—

[12 in.] Floating Gauge.	[5 in.] Gauge in Air.	[5 in.] Gauge in Water.	[5 in.] Gauge greased in Water.	[5 in.] Gauge painted white in Water.
Inches.	Inches.	Inches.	Inches.	Inches.
3.665	6.355	5.495	4.085	4.175

"In the case of the gauge greased regularly, the coating was so slight that no oily matter ever appeared on the surface of the water. The size of the instrument had a marked influence on the amount of water evaporated, for the larger the vessel, in proportion to the area, the smaller was the marginal ring up which the water passed by capillarity, and from which it was evaporated."

That a little paint reduced the evaporation from 5.495 to 4.175 in., or 34%, is interesting and instructive.

* *Minutes of Proceedings*, Inst. C. E., Vol. LXXI, pp. 47-48.

Mr. Hawgood.

It does not appear that land pan observations can have any bearing on evaporation from open water. The water temperature and the vapor tensions at that temperature and at the temperature of the air are controlling elements in the depth of evaporation. The closer the water in the pan represents the temperature of the open water, the closer will the pan evaporation be to the open water evaporation. The water in a land pan partakes of the temperature of the surrounding ground, and can have no true relationship to the temperature of an adjacent body of water. The varying ratios between land pan and floating pan evaporations for different seasons of the year show the lack of influences in common, if anything is needed to show such a point.

If the pan is insulated from the earth, as is sometimes done, conditions are rendered still more dissimilar. On clear dry nights the insulated pan would sustain great loss of heat by radiation; it calls to mind the practice common in some parts of India and elsewhere of making ice by just such a process. The environments of any land pan are so void of parallelism with open water that the results they exhibit cannot be considered otherwise than equally at variance.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

THE ECONOMICAL TOP WIDTH OF NON-OVERFLOW DAMS

Discussion.*

By Orrin L. Brodie, M. Am. Soc. C. E.

Orrin L. Brodie,† M. Am. Soc. C. E.—The author has indicated the range in the economic top width of non-overflow dams as varying from about 10% to a little more than 17% of the height, according to the assumptions of design. Such discussion, if academic, as the author fears, is not without value if it helps in any way to fix the ideas. Mr. Brodie.

The lower limit of 10% has been recognized for some time as of practical value; but, in connection therewith, the factors affecting width, besides pure economy, should not be neglected. The speaker refers to requisite width of roadway across the top of the dam, drainage wells within the body of the structure, and upper inspection gallery in a longitudinal direction, all of which require space which in large part often governs in fixing a top width. Incidental to some of the above should be mentioned the architectural treatment of railing or parapet, which is also closely related to the coping and cove stones or blocks, space for which must be provided at the top of the dam and so as not to encroach on the interior passageways, if any, at the top.

The author expresses a belief that the prevailing opinion of engineers is that the triangular dam (presumably with the apex at the water surface) provides the minimum section for fixed assumptions. Although the triangular section is theoretically fitted to withstand a horizontal liquid pressure intensity, increasing downward from zero

* This discussion (of the paper by William P. Creager, M. Am. Soc. C. E., published in November, 1915, *Proceedings*, and presented at the meeting of January 5th, 1916), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† New York City.

Mr. Brodie. at the top, the speaker seriously doubts that such general opinion prevails, for, unless he is much mistaken, it must be obvious to any one having to deal with the design of dams, especially high ones, that there is no economy in a triangular profile, in all cases, over one with a wider top, for the superimposed weight of the latter would result in correspondingly shorter bases in the lower portion than would obtain for a triangular cross-section. Furthermore, where uplift is considered active, it should be remembered that its tendency to overturn the structure is a function of the length of base.

The speaker noted the omission of consideration of ice pressure in the studies presented, except for passing mention. A study of its effect on the percentages deduced, should prove interesting.

As nothing is stated in the paper concerning the superelevation of the top of the dam, it is to be doubtless inferred that the top in each case was taken flush with the water surface.

At the risk of being tedious, perhaps, the speaker will continue his discussion, also in a way that may be said to be somewhat academic; but, to illustrate what effect on the cross-section consideration of ice pressure and of superelevation of the top has, and to compare ordinary sections with the triangular, four cross-section designs, *A*, *C*, *F*, and *D*, have been prepared, the base of each of which is subject to a head of 100 ft., the top in every case except the triangular dam, *D*, being 10 ft. wide.

The method of design is identical with that outlined previously* by the speaker. In fact, two of the cross-sections were taken from the earlier discussion and extended.

A is designed for 21 500 lb. per lin. ft. of dam, ice pressure at water surface; uplift intensity in joint of two-thirds of the head at the up-stream edge of each joint, diminishing to zero at the down-stream edge, and the horizontal thrust of the water. The relative density of the masonry is assumed at $2\frac{1}{4}$. The resultant is nowhere outside of the middle-third limit of the joint in question.

The same conditions, with the exception of ice pressure, apply to the other three sections.

Section *A*, as brought out in the discussion previously referred to, required a superelevation and top width of at least 10 ft., that is, no practically satisfactory cross-section resulted from the analytic design with lower values for the top width and superelevation.

Section *C* was assumed to have a superelevation of 7.5 ft., and Sections *F* and *D* have their tops at the reservoir surface.

In comparing these sections, note how the down-stream face of the triangular section (*D*'s) is everywhere down stream or exterior to the respective faces of Sections *F* and *C*. Similarly *F*'s face is ex-

* In discussion of "Provision for Uplift and Ice Pressure in Designing Masonry Dams", by the late C. L. Harrison, M. Am. Soc. C. E., *Transactions*, Am. Soc. C. E., Vol. LXXV, p. 174.

terior to C's. This shows, in part, the effect on the cross-section of the superelevation (C) and sensible top width of the dam (F). Mr. Brodie.

With regard to the up-stream faces, however, it is to be noticed that where C's down-stream face was the innermost, it is now the outermost, with respect to the sections. F is still intermediate with respect to the positions of D's and C's up-stream faces.

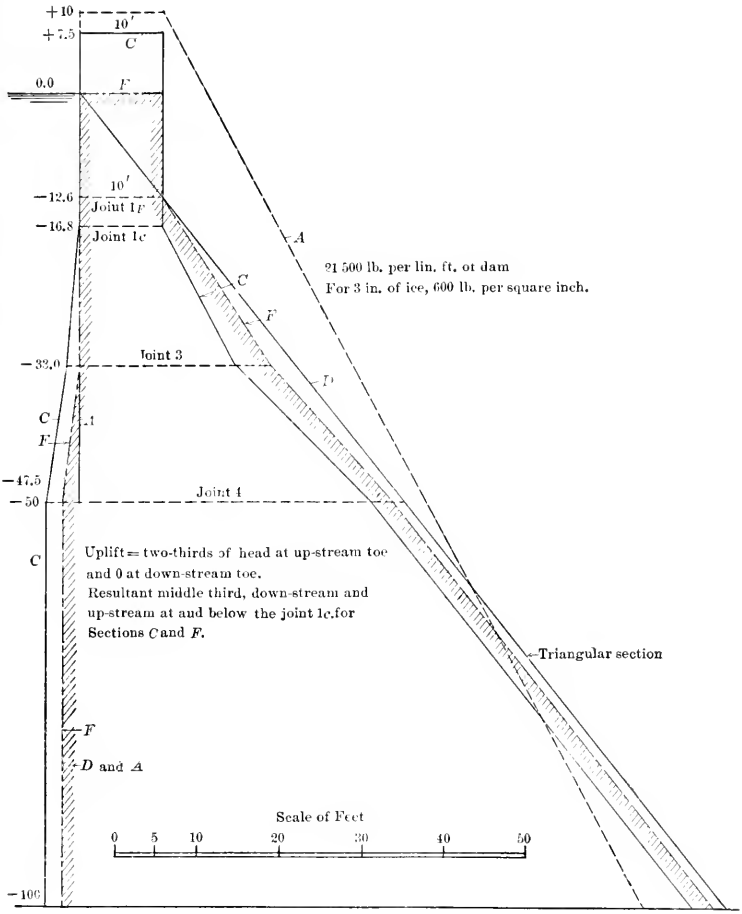


FIG. 3.

The ice-pressure section, it will be observed, encroaches within the other sections toward the bottom.

Table 4 gives the areas and bases, etc., of the cross-section for depths of 50 and 100 ft.

Mr. Brodie.

TABLE 4.

Cross-section.	Conditions.	50 Ft. Depth of Water.		100 Ft. Depth of Water.			
		Area, in square feet.	Base, in feet.	Area, in square feet.	Top width, in feet	Super-elevation, in feet.	Base, in feet.
A.....	Ice, horizontal and upward.	......	....	4 375	10	10	69.0
C.....	Horizontal and upward.....	999.0	39.5	3 969	10	7.5	79.3
F. ...	Horizontal and upward.....	998.0	40.0	3 973	10	0	79.0
D.....	Horizontal and upward.....	992.5	39.7	3 970	0	0	79.4

Ice = 21 000 lb. per lin. ft. of dam.
Uplift = two-thirds of the head at the up-stream edge of the joint, decreasing uniformly to zero at the down-stream edge.
Specific gravity of masonry = $2\frac{1}{4}$.

Turning attention now to the quantities of masonry involved, the result presents itself that, save for the ice-pressure section, *A*, all the sections are practically of the same volume, therefore it may be concluded that, for a given width, the superelevation affects, not the quantity of material, but only its distribution in the cross-section.

The quantity of material in the cross-section would seem to depend on the top width, to a certain extent; but more on the forces assumed to be acting on the dam. Although the superelevation thus has its effect on the shape of the cross-section, the practical questions of rise of reservoir due to flood, wave height, etc., determine in large part what superelevation is desirable.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

A REVIEW OF THE REPORT OF CAPTAIN ANDREW TALCOTT CHIEF ENGINEER MEXICO AND PACIFIC RAILROAD EASTERN DIVISION FROM VERA CRUZ TO MEXICO EXPLORATIONS SURVEYS ESTIMATES 1858

Discussion.*

BY MESSRS. T. K. MATHEWSON AND H. T. DOUGLAS.

T. K. MATHEWSON,† M. AM. SOC. C. E. (by letter).—The wealth of information, both historical and technical, contained in Mr. Low's paper will be a revelation to most engineers, even to those who have often passed over the Mexican Railway. That it was located, and to a great extent built, by American engineers will be news to those who have always heard it spoken of in Mexico as "The Queen's Own". The road has always enjoyed an enviable reputation for safety, in spite of the sharp curves and steep grades. Mr. Mathewson.

The Maltrata Incline, with its 4% grades and great curvature, would seem to offer an attractive field for electrification. The nearness of water-power and the absence of snow and sleet make the conditions favorable. It is the writer's belief that such a change in motive power has been considered by the company. It is his understanding that a masonry flume was built in one of the streams, possibly the Atoyac, in which to make measurements of the flow, under the direction of the late George Foote, who was at one time Chief Engineer of the road. Possibly the articulated Fairlie engines, with their short wheel base, make electrification less attractive. This may well be the case, as fuel oil from the Tuxpam oil fields, near-by, is now used in place of

* This discussion (of the paper of Emile Low, M. Am. Soc. E., published in December, 1915, *Proceedings*, but not presented at any meeting of the Society), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† Muscatine, Iowa.

Mr. Mathewson. coal briquettes from England. Details of these engines would be interesting, as they are one of the unusual features of the line.

The description and history of this interesting railway could hardly be more complete, in spite of the fact that the disturbed condition of Mexico has made communication with the country very difficult at this time. The paper will be especially interesting to those who know and love Mexico.

Mr. Douglas. H. T. DOUGLAS,* Esq.—Mr. Low is to be congratulated on the complete description of the Mexico and Pacific Railroad, the location and construction of which furnish one of the best examples of bold engineering—especially from Tejiera to Boca del Monte—to be found on this continent.

The writer had the honor to serve under Col. Talcott in locating the line from Paso del Macho to the Rio Metlac, and in constructing "The Division of the Boot" (La Bota) in the center of which the Village of Maltrata is situated. He also served under Col. Talcott in Virginia.

Col. Talcott belonged to a period which furnished some of the most distinguished engineers to America—the pioneers who blazed the way. Among them were Messrs. Charles B. Fisk, Charles Ellett, and Benjamin Latrobe, and Colonels Claudius Crozet (a soldier of Napoleon's great army), C. F. M. Garnett, and Walter Gwynne—a galaxy the like of which is rarely found. In this company of great engineers, Col. Talcott, because of his high professional attainments and exalted character, measured up to the highest mark, and the writer recalls his service under him with the greatest pleasure as it supplied a lesson which has never been forgotten.

Col. Talcott's sons, Charles, Richard, George, and T. M. R. (the latter a Colonel and Aid-de-camp to Gen. Robert E. Lee), all distinguished engineers, were the writer's personal friends and associates; he also recalls his service on this railroad with Messrs. William Cross Buchanan, Sebastian Wimmer, Richard Ingalls, and Dr. Manifred, with much pleasure.

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* New York City.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

CHEMI-HYDROMETRY AND ITS APPLICATION TO THE PRECISE TESTING OF HYDRO-ELECTRIC GENERATORS

Discussion.*

By Messrs. George W. Fuller, W. D. Peaslee, W. L. Waters, Robert E. Horton, and Thomas H. Wiggin.

George W. Fuller,† M. Am. Soc. C. E.—It occurs to the speaker that there is one phase of this subject which no doubt has been adequately considered by the author, but which is mentioned in the hope that it will lead to some discussion. Reference is made to the diffusion in water of solutions of chemicals such as salt. Mr. Fuller.

Some years ago, when the speaker was connected with the Lawrence Experiment Station of the Massachusetts State Board of Health, solutions of salt were used to measure the actual period of flow of liquids through sedimentation tanks. The purpose was to ascertain the actual detention period of the liquid in the tank, as compared with the theoretical period obtained by dividing the capacity of the tank by the actual flow into and through it. By the use of salt applied to the entering water, and by tests of the effluent to determine how quickly the salt actually passed through the tank, information was obtained as to the extent which short-circuiting and other factors cause the actual detention period for part of the water to be less than the average or theoretical detention period.

Solutions of salt were also used at Lawrence to determine the water content, that is, the quantity of water held by capillarity in intermittent sand filters, in connection with studies to ascertain the best rate at which to operate the filters. Here, too, solutions of salt

* Discussion of the paper by Benjamin F. Groat, M. Am. Soc. C. E., continued from January, 1916, *Proceedings*.

† New York City.

Mr. Fuller. were added to the influent, and its rate of travel through the filter was determined by the tests of the effluent, in order to note the increases in salt content above the normal.

At many places, in recent years, in connection with the purification of water and sewage, use has been made of salt solutions and of aniline dyes to develop information along the lines just stated. Obviously, this use of salt solutions is somewhat different from that described by the author. In fact, it deals particularly with liquids moving at an extremely low velocity, whereas relatively high velocities would be used in a head-race in connection with tests of a hydro-electric plant.

However, it may be of some interest to mention that, at Lawrence, the diffusion of the solutions of salt proved to be a bothersome factor; in fact, some salt was found at the outlet of the tanks and filters at an interval so short after its application to the influent as to point most strikingly to the influence of diffusion. It is very likely that the use of salt for the purpose described so interestingly by the author would not involve similar complications, notwithstanding the fact that diffusion is a particularly disturbing element when applied under some conditions, as at Lawrence.

Mr. Peaslee. W. D. PEASLEE,* ESQ. (by letter).—This classical paper is a very welcome and timely contribution to the literature of this subject, and Mr. Groat's masterly treatment is not a surprise to those who are familiar with his professional work.

However, the writer fears that the very mastery shown by this paper will cause the average engineer to regard what Mr. Groat so aptly terms, "Chemi-Hydrometry", with a certain degree of misgiving, in that it would seem, on account of expense and intricacy, to be applicable only to those particular cases wherein the magnitudes and money involved warrant such a precision study as described. Although the degree of research and precision outlined in the paper is, of course, necessary in a test of the magnitude of this one, there is no limit to the field of this method when properly applied.

The writer has been working on this subject for more than 2 years, and although, on account of the high heads and small discharges common in the West, occasion has never arisen demanding the measurement of discharges greater than 300 sec-ft., a method has been developed† wherein several features have been worked out tending toward a greater simplicity of procedure, and sacrificing to only a small degree the accuracy secured by Mr. Groat.

The measurement and maintenance of the dosing rate is secured with the equipment shown by Fig. 40. Various sizes of nozzles, to fit

* Dept. of Elec. Eng., Oregon Agricultural Coll., Portland, Ore.

† *Journal of Electricity, Power and Gas,* August 21st and 28th, 1915.

the lower end of the pipe, are made, and the equipment can thus be calibrated for several different dosing rates, maintaining, with the hook-gauge, a constant head over the nozzle. As is well known, a properly designed nozzle orifice is one of the most accurate methods of determining small discharges. With this equipment the stop-watch error is almost entirely eliminated, as the calibration can be made over a long period of time. Also, as the calibration can be made with the dosing solution used, the effect of temperature and therefore of density can be eliminated. It has been found feasible to hold and determine the dosing rate within a total error of 0.1 of 1 per cent. Mr. Peaslee.

This equipment has now been in use for several months, in the following rather interesting way: A Central Station Company, carrying a rather large rural pumping load, has equipped an automobile with this apparatus, a quantity of salt, sample jars, electric meters, and a large tank. At certain intervals, two men with this outfit make the rounds of every pump on the company's lines and make discharge measurements of the pumps by this method, and at the same time take electrical input readings. The samples taken are sealed in jars and, with the meter readings, are sent to the chemist at the main office, where they are analyzed. In this way many very valuable data are secured at very small expense to the Company and with no trouble to the pump men. The capacities of the pumps range from 40 to 4 000 gal. per hour, and these two men, now that they are used to the work, can set up and run a test in a remarkably short time. The writer feels sure that the error in the results from these tests is 0.5 of 1% or less.

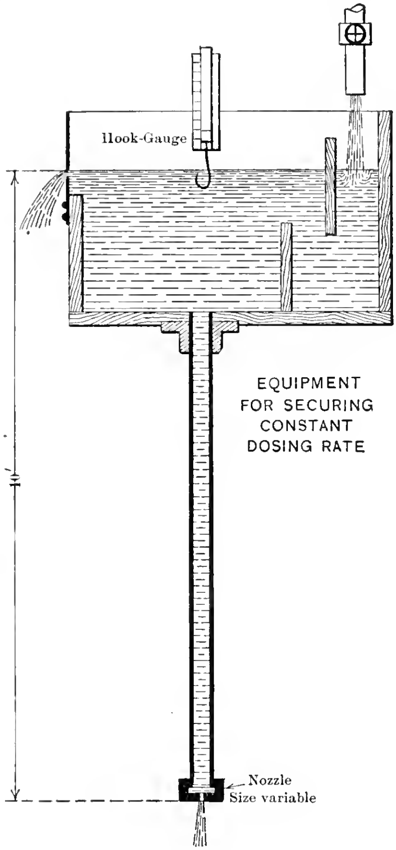


FIG. 40.

The point the writer wishes to bring out is that, especially for small discharges, it is possible, by the sacrifice of a very small degree

Mr. Peaslee. of the accuracy of Mr. Groat's work, to have a method which will not appear to the average engineer as formidable as Mr. Groat's paper would suggest; and is, at the same time, cheaper than almost any other determination, and more accurate than most test conditions warrant.

As there is only a very brief reference to the electric method of determining the salt content of samples, the writer will add a short description of some work he has done, using this method.

The following factors enter into and must be taken account of in any method involving the electrical determination of the salt content of samples:

1.—Temperature has a distinct and accurately known effect on the electrical conductivity of any saline solution. The curve of Fig. 41 shows this variation as it has been determined experimentally, verified by mathematical computation based on chemical theory.

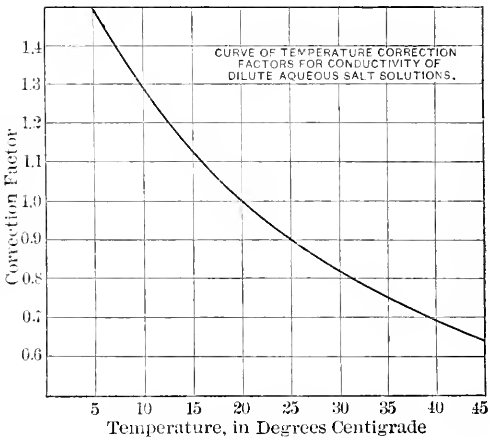


FIG. 41.

2.—There is a counter electro-motive force of polarization that must be corrected for or taken into account in the calibration of the apparatus. For weak salt (NaCl) solutions and bright platinum electrodes, this is constant and a little less than 2 volts.

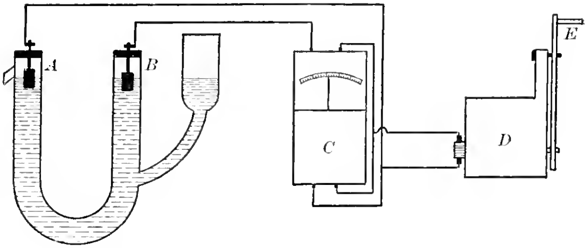
3.—Means must be provided for thorough cleaning of the apparatus, in order to maintain the integrity of the different samples.

4.—The formation of gas bubbles on electrodes must be prevented, or account must be taken of their effect.

The equipment shown by Fig. 42 has been developed and has proved successful when determinations on the samples within 0.1 of 1% are satisfactory, and further work is being done toward a refinement of this method. In this figure, *A* and *B* are bright platinum electrodes of special design to prevent bubble formation; *C* is a conductivity meter; and *D* is a direct-current generator of suitable design. The whole equipment can be made very compact and portable.

It is calibrated with known solutions, and a curve, such as Fig. 43, is obtained which takes into consideration the variations in cross-sections of the tube, the counter electro-motive force of polarization.

Mr. Peaslee.



APPARATUS FOR ELECTROLYTIC DETERMINATION.

FIG. 42.

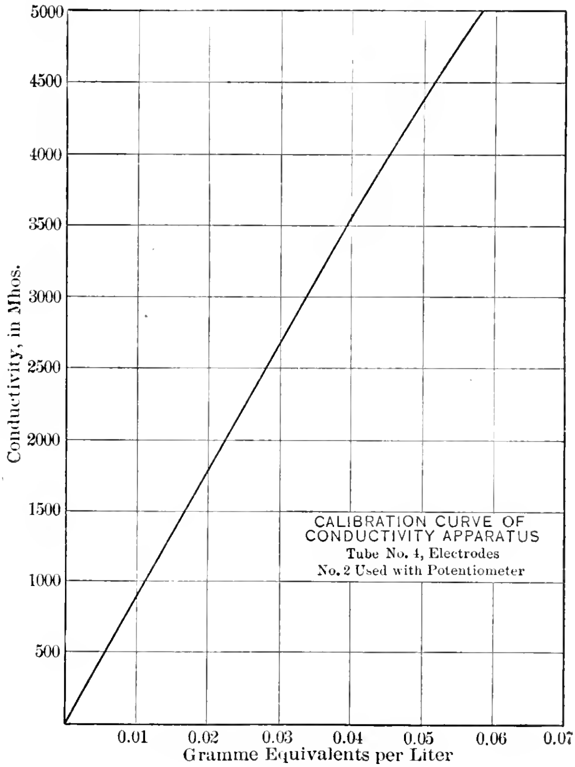


FIG. 43.

Mr. Peaslee. and individual characteristics of the meter. With this equipment and the method of special dilutions much of the tedious titration work is avoided, and the experience of a year's work leads the writer to depend on this method and equipment to within 0.1 of 1 per cent.

The field of this method is very wide, as it can be used for cheap, accurate tests on small discharges, up to, say, 500 sec-ft., and, with a corresponding increase in expense and care, can be used as a precision method on discharges of almost any magnitude.

The engineering fraternity owe a large debt of appreciation to Mr. Groat for his remarkably able presentation of the theory and practice of this method in such complete form.

Mr. Waters. W. L. WATERS,* ESQ. (by letter).—This paper covers in a very complete and thorough manner the technique of conducting an efficiency test on hydraulic turbines by the salt-solution method, but, in view of the great detail of the tests, the writer thinks that Mr. Groat could, with advantage, publish some additional figures in connection with the readings.

The principle of this test with a salt solution is that brine added to the water in the forebay becomes uniformly mixed with the whole water supply of the turbine. It is evident that, if the efficiency of the forebay and turbine were 100%, there would be no eddies in the water to enable the brine to mix and form a solution of uniform density with the whole of the water supply. The brine, when added in the forebay, would simply move in stream lines parallel to those of the water supply, so that it would not mix.

In each test, Mr. Groat takes eighteen samples of the tail-race water, and it is probable that a comparison of the figures obtained for each of these eighteen samples would give a very fair idea of the extent to which the brine solution becomes uniformly mixed with the forebay water in the average high-efficiency modern turbine.

If it is found that the brine does not mix very satisfactorily in an efficient turbine, it would indicate that difficulties may be expected in applying this otherwise very attractive test to the case of turbines with a very high efficiency. It is probable that the figures obtained by Mr. Groat will enable a fairly definite opinion to be formed as to the degree of mixing obtained, if the results obtained in each test of the various eighteen sample tubes in the tail-race are given. On this point Mr. Groat could add greatly to the value of the paper if he would give some additional test figures.

Mr. Horton. ROBERT E. HORTON,† M. AM. SOC. C. E. (by letter).—Any one who has undertaken an original investigation in a new field must realize the enormous amount of painstaking and careful labor which has

* Pittsburgh, Pa.

† Albany, N. Y.

been involved in the preparation of Mr. Groat's paper. On looking it through, it appears that he has presented the original data fully, freely, and without reserve, thereby setting an example which may be properly followed by others offering the results of original investigations. As a rule, even though errors may be found, the results of such an investigation are likely to inspire greater confidence, and are certain to be more useful in assisting future progress in the work if presented in full, as has been done here. Mr. Horton.

The author suggests the use of the term "chemi-hydrometry" to describe the measurement of the volume of flowing water by the introduction and subsequent detection of chemicals. As he suggests, this name is not very satisfactory. The terms "hydrometry" and "hygrometry" have been pre-empted, unfortunately, to describe somewhat limited special aspects of the measurement of water. There is great need for some term to cover all classes of measuring water, itself an art of far-reaching importance. In fact, there is need for a general revision of hydraulic terminology. The term "hydrography", sometimes used to describe the measurement of water, should be limited in its application to the mapping of waters, giving it a meaning somewhat analogous to the words "topography" or "geography" in relation to the mapping of lands. Hydrology, in its broad sense, covers every aspect of the science and phenomena of waters, but should generally be used in the more restricted sense of the science covering the laws and phenomena of occurrence and distribution of waters in their natural state. It would thus include the phenomena of precipitation, evaporation, yield and regimen of streams, and the flow of ground-water. In this sense, the word ""hydrology" is akin to the word "geology" in relation to the solid materials of the earth.

The writer suggests the use of the term "aquametric", as being both available and expressive, to describe matters relating to the measurement of water in general. Thus an aquametric survey would be a survey for the purpose of determining the quantities of water in a region. In the present instance, as the measurement is accomplished by the use of salt, the process might be denominated a "sal-aquametric" method.

Regarding the current meter, the writer believes it is a much abused instrument, and, at the same time, its value and utility are often greatly over-estimated. Under suitable conditions, it may quite certainly give results of a single measurement of a stream accurate within less than 1 per cent. This would require that the channel be of sharply-outlined, definite, and well-determined cross-section, and that the stream should be flowing below the critical velocity, so that stream line, or filamentous, flow takes place. The writer concluded some years ago that there was danger in accepting current-meter ratings made in still water as being always applicable to flowing water.

Mr. Horton. Until recently, the reasons for this do not appear to have been set forth satisfactorily. A recent book* shows logically and conclusively that errors such as have been referred to might exist, and that their cause rests essentially in the difference in fluid resistance under conditions where the fluid is static and the object is moving, as compared with the resistance where the object is quiescent and the fluid is moving in a non-uniform or sinuous manner. Experiments on the flow in pipes show that the critical velocity at which motion changes from the stream line system to the vortical flow is not the same when the fluid velocity is gradually increased, as it is when the velocity is decreased from a higher to a lower limit.

As illustrating the conditions under which highly accurate results may be obtained with a current meter, Fig. 44 is presented, showing the velocity contours in a cross-section of a flume, of smooth, planed plank, specially constructed for the purpose of measuring the stream, the velocities being taken with a current meter suspended from a framework in such a manner that the exact position of the center of the meter could be determined with a high degree of accuracy.

As an illustration of the uncertainties of current-meter work unless proper precautions are taken, the writer recalls an instance which occurred a number of years ago. A dam was being used as a weir for the purpose of measuring the yield of a stream on which a power plant was to be constructed. It was known that there was considerable leakage through the dam, and an attempt was made to determine the volume of this leakge in the early winter, at a time when there was some water flowing over the crest of the dam, and it was impossible to draw the water down to crest level. There was a masonry aqueduct across the stream a few hundred feet below the dam. This aqueduct had about a dozen archways, and was constructed with a parapet over which one could look vertically down to the water surface, but it was impossible from any position on the aqueduct to look under the archways. The idea was to make a current-meter measurement of the flow under this aqueduct, subtract from the measured flow the calculated flow over the spillway, the remainder being the indicated leakage through the dam. The writer is informed that the measurements were made by current meter in the usual manner, and that from surface indications there was apparently a uniform current at right angles to the aqueduct passing under each archway. The stream was probably turbid at the time, so that it would have been impossible to observe the position of the submerged meter had an effort been made to do so. These measurements indicated an apparent leakage through the dam of 315 cu. ft. per sec., which the writer is informed was accepted as a basis for estimating the low-water flow of the stream in connection with the proposed power development. Being suspicious of these

* "The Motion of Liquids," by R. De Villamil.

Mr. Horton.

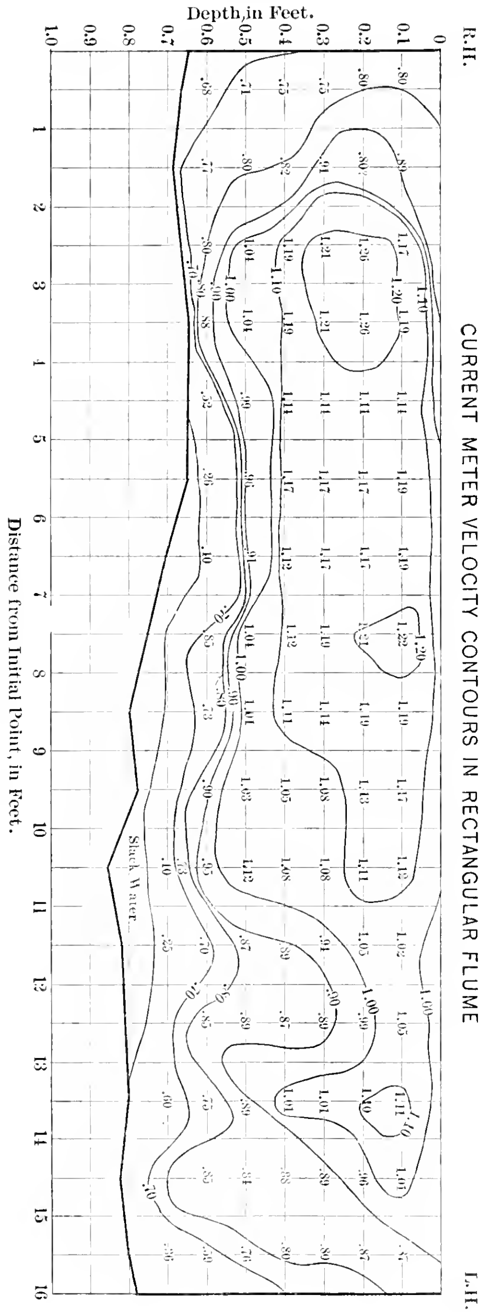


FIG. 44.

Mr. Horton. results, the writer undertook to make an independent determination of the leakage through the dam in the following summer. Examination of the aqueduct showed that most of the leakage came down the right-hand side of the stream; reaching the up-stream side of the aqueduct, the current was deflected across the stream, and the flow finally passed out under the left-hand arch. The deflection of the current was caused by the existence of old falsework under all the archways except the one on the left-hand side of the stream. At the time the writer's observations were made, the water was drawn down to the crest of the dam, but further observations showed that, when there was a sufficient volume of water wasting over the dam, the water would spill over the obstructions under the archways in such a manner that there was an appreciable surface current directly down stream, although the main flow was across the stream channel. Apparently, the current meter had been headed across the stream, and the same water had been measured over and over again, as careful measurements by wading, where the leakage through the dam was concentrated in a single channel, indicated the actual leakage at crest level to be only from 35 to 45 cu. ft. per sec.

The power development based on the erroneous measurements was a failure. The writer had nothing to do with the original measurements, and did not receive any very cordial thanks for calling attention to the error, as the owners of the proposed power development were just at that time attempting to issue additional bonds to complete their construction.

Sal-aquametric turbine testing is evidently laborious, requires a great refinement of methods, and is costly. There appear to be many situations where it would be difficult to apply this method in practice. The same may be said of any other method of water measurement in particular cases. Therefore, no single aquametric method should be either universally condemned or accepted to the exclusion of all others.

Mr. Wiggin. THOMAS H. WIGGIN,* M. AM. SOC. C. E.—The author is to be praised for the care with which he has worked out all sources of error. Probably some of these errors would never require attention in ordinary tests; but it is well to know the sources of even small ones and to have them explained so that they may be avoided. The speaker has had something to do with testing machines, and knows how easy it is for errors to be overlooked. For example, on so simple an apparatus as a mercury gauge for showing heights of water, there are several sources of error which are commonly neglected, and could amount to quite a percentage. The speaker remembers one pumping engine test where unusual care was taken, there being a good-sized bonus in

* New York City.

question, but in which one source of error which was not taken into account amounted to several thousand dollars. Mr. Wiggin.

The question intrudes itself, however, as to whether it is ever justifiable to write a specification in which the degree of accuracy indicated by the author is attempted; in other words, whether the cost of testing is not more perhaps than the amount involved, and whether still further refinement might not prove the apparent precision to be in part fictitious. Furthermore, is the quantity to be measured—namely, the efficiency of the turbine—sufficiently constant for a considerable period of time to justify such precision? It would be of interest if the author could state whether, after a week, 10 days, or a month, this same machine, tested to the same accuracy, would show the same efficiency. Perhaps the author can tell of tests conducted at intervals on the same turbine which would show whether the machines changed.

A water-works engineer is glad to get a Venturi meter in his line which will enable flows to be measured to within 1% or so; but it is not always possible, and occasions come to the speaker's mind in which the author's method of measuring flows will be indispensable, particularly when it is reduced to its simplest terms. The speaker presumes that the actual performance of such tests, now that the author's exhaustive investigation has been completed, will be much less formidable than is indicated by an examination of the paper and the illustrations.

The cost of these investigations must have been considerable, and the author and others who have generously contributed the results to the Engineering Profession deserve thanks and appreciation. It would be of interest if the author could state, roughly, the probable cost of a future test conducted with the care indicated, now that the method has been established; also, for purposes of comparison, rough figures for the commercial value of small increases in turbine efficiency, justifying extreme precision in such tests.

AMERICAN SOCIETY OF CIVIL ENGINEERS

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PAPERS AND DISCUSSIONS

THE ACTION OF WATER UNDER DAMS

Discussion.*

By Messrs. H. W. King, Robert E. Horton, and J. B. T. Colman.†

H. W. King,‡ M. Am. Soc. C. E. (by letter).—Mr. Colman deserves great credit for having made a careful and systematic study of an important engineering problem of which but little is known. The engineer is confronted with this problem whenever he undertakes the design of a dam, and especially a dam of the type commonly constructed on earth foundations. At present there seems to be no uniformity of practice among engineers in allowing for upward hydrostatic pressure. Cases might be cited in which no allowance was made for such a pressure, and in other cases allowance has been made for a pressure equal to that exerted by the total head under the entire base of the dam. Mr. King.

The point at which the resultant pressure under a dam should be applied is an important consideration, as is also the effect of sheet-piling on upward pressure and in reducing seepage. The author's experiments throw much light on all these important points.

The writer was in close touch with Mr. Colman during the progress of these experiments, and there is no doubt that each detail was worked out with great care and thoroughness. It does not seem probable that much more data could be secured from a series of experiments of this nature than were obtained by Mr. Colman. Some inconsistencies appear in the results, but, in a great measure, these may be explained, and do not necessarily detract seriously from the value of the experiments as a whole.

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* Discussion of the paper by J. B. T. Colman, Assoc. M. Am. Soc. C. E., continued from December, 1915, *Proceedings*.

† Author's closure.

‡ Ann Arbor, Mich.

Mr. King. The criticism has been made that the scale of the experiments was too small, and that a larger model would give more reliable results. This may be true, but Mr. Colman's model was approximately 10 ft. high and 16 ft. long, and a much larger one would hardly be feasible. Experiments on a larger scale must be made on existing dams, and it should be possible to obtain much valuable information in this manner. Such data, however, must necessarily be incomplete, and experiments on models like Mr. Colman's will be valuable in interpreting and extending them.

One important point brought out by these experiments was that sheet-piling, to be effective in preventing upward pressure, must be absolutely water-tight. The importance of this fact was not realized early in the investigation, and proper precautions were not taken with the first piling to prevent leakage. It was found that the effect of such piling could scarcely be noticed. This condition was changed immediately, however, when the piling was made impervious.

The effect of tight piling may be seen from Figs. 11 and 12. With no piling, for a depth of water of 5 ft. above the dam, the upward pressure head just below the dam is approximately 4 ft., and, with 1-ft. sheet-piling at the heel of the dam, it is 2.5 ft.

Unfortunately, the relation between length of piling and total upward pressure cannot be seen from these experiments. There can be no doubt that the upward pressure must decrease as the piling is lengthened, but, from Figs. 13 and 14, the opposite appears to be the case. This anomaly the writer believes is due to leaky sheet-piling. In spite of the fact that every apparent precaution was taken to prevent leakage, it is probable that some water was able to find its way through the piling, and thus in a measure nullify its effect.

This principle has an important practical bearing on dam construction. It is a common practice to drive a row of sheet-piling at the heel of a dam. There is no kind of sheet-piling that can be considered water-tight, especially when the usual difficulties encountered in driving are taken into consideration. It would appear, then, that such piling has little or no effect in reducing upward pressure under the dam. The writer is of the opinion that a good impervious concrete cut-off wall of moderate depth will have a more beneficial effect in this regard than any quantity of sheet-piling.

The experimental data on seepage appear to be a little conflicting. The writer believes, however, that a cut-off, to be effective in reducing seepage, must be water-tight and extend into an impervious stratum. Frequently, the seepage losses through the banks around a dam are a more important consideration than seepage under the dam.

The author submits a formula for determining the total upward pressure on the base of a dam. This formula has been shown in earlier discussions to be inapplicable in extreme cases. This is only to be expected, as the formula, which is derived from a small number of points, all in the lower limits, has no theoretical basis. No empirical formula of this kind can be used with real assurance beyond the range of the experimental data on which it is based. Mr. King.

It may be seen from Figs. 9 to 15, that, for any experiment, if a straight line is drawn from a point corresponding to the depth of water above the dam to the toe of the dam, this line will, in general, lie above the pressure line corresponding to this experiment. From this it appears that if the upward pressure on the base of the dam is taken as the hydrostatic pressure due to one-half of the head against the dam, the assumption will be safe. It seems reasonable to assume that this rule should apply to higher heads and larger dams.

An examination of Table 5 shows that, with sheet-piling at the heel of the dam, the upward pressure is equal to about three-tenths of the total hydrostatic pressure. The experiments with 2-ft. and 3-ft. piling would doubtless show a total pressure less than this, if there had been no leakage through the sheet-piling. The author has pointed out the fact that an impervious cut-off at the toe of a dam will increase the upward pressure and move the point of application of the resultant pressure down stream.

Using the author's notation, in which H, L, and P represent, respectively, the head of water against the dam, the length of cross-section of the base of the dam, and the total upward pressure per unit length of dam, the following simple formulas should be safe guides in determining upward pressure:

(1) With no cut-off at the heel of the dam or with ordinary sheet-piling,

$$P = \frac{62.4}{2} H\ L = 31\ H\ L;$$

(2) With an impervious cut-off at the heel of the dam,

$$P = \frac{62.4}{3} H\ L = 21\ H\ L.$$

The point of application of the resultant, P, is $\frac{1}{3} L$ from the heel of the dam.

Both samples of sand used in these experiments were comparatively clean. It seems probable that a sand having the voids well filled with silt would show a smaller pressure. It would hardly seem safe, however, under any conditions, to assume a pressure smaller than that determined from these experiments, as earth in its natural state may not be of uniform mixture, and a seam of sand may be the controlling factor in producing pressure, rather than an average mixture of the material under the dam.

Mr. Horton. ROBERT E. HORTON,* M. AM. SOC. C. E. (by letter).—The writer had the pleasure of examining the apparatus and methods while this investigation was in progress, and has full confidence in the results, as far as they go. The data are well presented; the deductions are made in a logical and orderly manner; and the paper is an original and valuable contribution to experimental hydraulics. The writer fully realizes the labor and difficulties involved in prosecuting original investigations, and intends no criticism when he says that these results should be confirmed and extended by further studies.

In view of the great present-day importance of hydraulics, in water-power, water supply, irrigation, drainage, sewerage, and navigation—matters vital to life and indispensable to commerce—efforts should be made to provide additional hydraulic laboratories and means to conduct experimental hydraulic and hydrological work therein along much broader lines than ever heretofore attempted. The average layman has a misty conception of the functions of a hydraulic laboratory; the average engineer probably looks on it as a place where neat little experiments are performed to illustrate to students the flow of water over weirs or through orifices under ideal conditions. That is a useful function, but much greater service may just now be rendered by providing means whereby life-size experiments on a wide variety of subjects may be carried out. There is hardly a subject in the domain of formal hydraulics that does not need a great deal of large-scale experimental work, and there are many subjects which have been scarcely touched experimentally; such, for example, as the phenomena of the standing wave. Furthermore, there are several subjects—in connection with dams, for example—in relation to which present-day design is based largely on very arbitrary assumptions.

The phenomena of the causes of floods, low-water flow of streams, yield of wells, evaporation, and many other hydrologic subjects could be investigated to great advantage in a good hydraulic laboratory, yet such laboratory studies have never been undertaken to any extent.

Mr. Colman's paper is a good example of a clean-cut and valuable investigation, capable of being carried out at moderate expense in a hydraulic laboratory. Even on this subject, however, more could have been accomplished almost in direct proportion to the time and means available. For example: experiments on dams with longer bases appear to be desirable; and valuable results could be obtained by conducting experiments on earth dam sections with cores.

The experimental results given suggest that, for an earth dam of homogeneous material with an impervious core, and on a permeable foundation, the water under the part of the dam down stream from the core would rise by static pressure and the down-stream portion of the dam might thus be saturated to the same, or nearly the same,

* Albany, N. Y.

Mr. Horton.

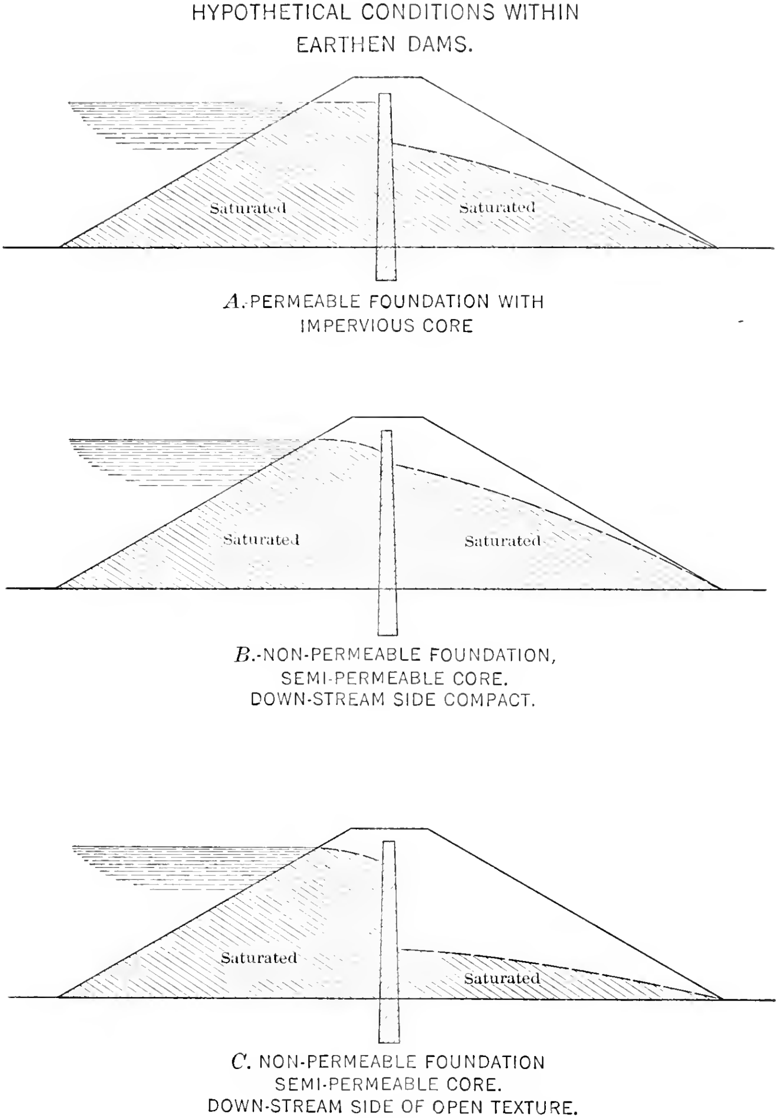
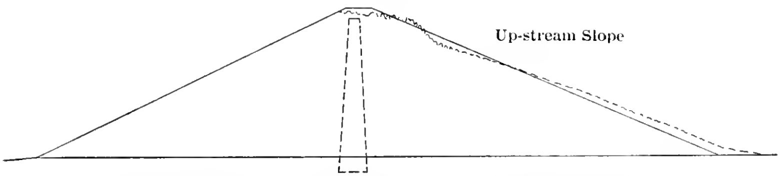


FIG. 19.

Mr. Horton. degree if the core was absolutely impervious as if it was somewhat permeable. If, on the other hand, the dam is on an impervious foundation and the core is somewhat permeable, the water just below the core will stand at a height below that in the pond, dependent on the resistance to flow afforded by the core and the freedom of outflow of the percolating water. Apparently, the more permeable the material on the down-stream side of the core the less will be the degree of saturation of the down-stream face of the dam.

As regards conditions within the portion of an earthen dam up-stream from an impervious core, experimental work is also needed to determine the best materials and their stability when saturated. These hypothetical conditions under earth dams are illustrated by Fig. 19. Confirmatory experiments are needed.

The failure of the Savage Reservoir, near Utica, N. Y., in September, 1902, was accompanied by a sloughing off of the up-stream face into the reservoir, as shown by Fig. 20.



CROSS-SECTION OF SAVAGE RESERVOIR DAM, NEAR UTICA, N.Y., SHOWING RELATIVE POSITION OF UP-STREAM SLOPE BEFORE AND AFTER FAILURE.

FIG. 20.

An incipient failure of a certain dam due to the slipping of the inner slope is reported, but it was checked by draining the water down below the opening left by the slip. Thus, it appears that the safe inboard slope of earthen dams needs experimental study.

These illustrations suggest a few of the many lines of experimental investigation needed in practical hydraulics.

Mr. Colman. J. B. T. COLMAN,* Assoc. M. Am. Soc. C. E. (by letter).—The writer has read the discussions with much interest. As a result of the radically different opinions therein expressed, his own ideas have been made more lucid. A small part of the discussion is not closely allied to the subject.

At the present time, very few data pertaining to the hydraulics of existing structures are available. "Such data", as Mr. King states, "must necessarily be incomplete, and experiments on models * * * will be valuable in interpreting and extending them."

* Detroit, Mich.

Mr. Colman.

Throughout the paper, and more especially in Fig. 1 and on pages 1297-1299,* the writer attempted to consider only structures of gravity type on homogeneous foundations. He acknowledges quite frankly that the size of his model was small when compared with a dam of gravity type having a head of 40 ft. or more. On the other hand, other investigators have been drawing conclusions from models with a capacity ranging from less than 1 cu. ft. up to 16 cu. ft. This model was approximately 16 ft. long, 4 ft. wide, and 10 ft. high.

The sands used were very uniform in analysis. Several samples, taken while removing them from the model, and afterward analyzed, showed almost identical results for each sand. At the same time, no indication of piping action was observed.

Before taking up the experiments, the ratio of the area exposed to pressure, the width of the dam, and the area at the toe, were carefully considered. It will be seen that the pressure curves show the same general form throughout. The high-pressure curves, in each case, for the 4.25, 6.25, and 8.25-ft. floors (Figs. 2, 3, and 4), start from the heel of the structure and slope forward in a direction that approximates the horizontal. The low-pressure curves, in each case, start from the toe and slope in a curve of similar form, but down stream from the structure. As might be expected, the latter curves are flatter for the shorter than for the longer floor length.

Again, attention must be called to the fact that there are no readings which would indicate a restricted entrance or exit. That which appears at first to be the result of insufficient exposed surface at the heel and toe of the structure is, as a matter of fact, the indication of the law sought. Unfortunately, Mr. Hays does not supply the data whereby he maintains that the published experimental work shows restriction of entrance and exit.

The difference in the readings of individual tubes is raised by Mr. Oakes, as shown by Nos. 2, 5, and 8, which are at the same elevation. In Fig. 21 the writer gives the leveling curves for these three tubes for Sand *B*. The method of plotting these curves is given on page 1303.* It will be seen that Tube No. 8 gives, for all three floor lengths, values less than those for Tubes Nos. 2 and 5. The same tube leveling curves for Sand *A*, with a single exception for Tube No. 2, hold the same relative position. That is, the lowest for all three floor lengths is Tube No. 8, then Tube No. 5; and the highest is Tube No. 2.

Throughout his work, the writer strove to forget the mathematical demonstration, as indicated by Mr. Muckleston, and given more fully by Parker† and others. This proof is very interesting, but is based on assumptions purely theoretical. One hardly needs to go into a

* *Proceedings*, Am. Soc. C. E., for August, 1915.

† "The Control of Water", by Philip A. Morley Parker, Assoc. M. Am. Soc. C. E., pp. 279–299.

Mr. Colman. discussion to show the weakness of a formula obtained as the result of the indicated operations.

Of course, when one admits the weakness of the mathematical equation, the objection to the tail-water standing above the sand level at the toe of the dam is removed. In practice, no one would expect to build a structure of gravity type and keep the surface of the tail-water just at the surface of the sand. An added precaution in this direction would rather detract than add to the usefulness of the data.

The writer is very much gratified indeed that other investigators, working along similar lines, have obtained results which agree wholly or in part with conclusions Nos. 1, 2, 3, and 4. It would seem that the partial disagreement of Mr. Hays indicates that he has worked with a small number of data, or with too few piezometer tubes.

It is hardly necessary to explain why the law of pressure, between certain limits, should resemble closely the curve of the law of error. In fact, there is no satisfactory mathematical proof that applies to the law of error itself. The point to be considered is that the writer, in attempting to determine a curve which would most closely fit the cases in hand, could find none that would approximate all points so nicely as the probability curve. It is hoped that other investigators, with more data at hand, may be able to determine a simpler curve, which can be solved directly.

Mr. Elliott and Mr. Creager state very correctly that, if the values of $\frac{H}{L}$ are increased to 1.75 and 1.4. respectively, the equation gives greater values than it is possible to obtain. It would seem to the writer that, for the time being, these two gentlemen lost sight of the fact that gravity-type dams on porous foundations are rarely constructed with a ratio of H to L greater than 1 to 2, and more often with a ratio of 1 to 5.*

In this instance, the curve was extended from three to seven times its practical limit. Judging from Mr. Creager's curve in Fig. 18, it would seem that the formula is not at fault for values of S less than unity. The writer was fully aware that his formula would not hold for structures on so-called impervious or semi-impervious foundations, into which classes structures with values of S greater than unity fall.

Mr. Oakes brings up the same question in a different form when he says, "For a 5-ft. head, the pressure at the heel, with bases 4.25 and 8.25 ft. long, is greater than that for the base 6.25 ft. long". It is very obvious that the pressure at all points is a function of the slope, that is, of both H and L. The 5-ft. head with the 4.25-ft. base is, as pointed out, above the working value of S. Under such a struc-

* The reader is referred to the paper entitled "Dams on Sand Foundations: Some Principles Involved in Their Design, and the Law Governing the Depth of Penetration Required for Sheet-Piling", by Arnold C. Koenig, Assoc. M. Am. Soc. C. E., *Transactions*, Am. Soc. C. E., Vol. LXXIII, p. 175.

Mr. Colman.

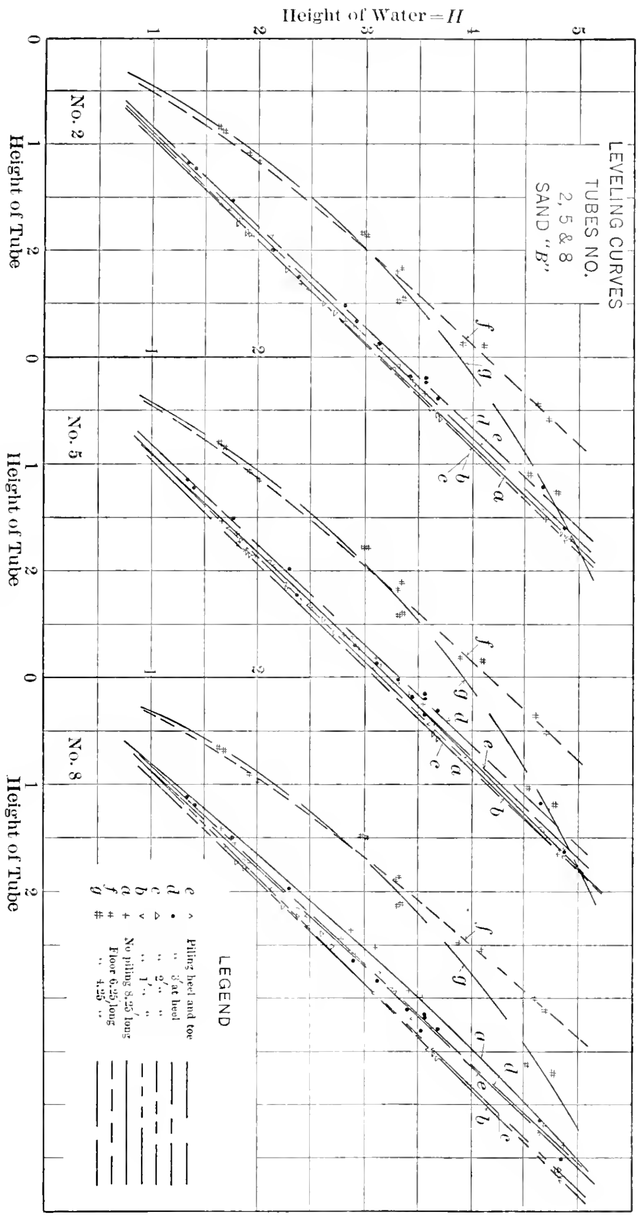


FIG. 21.

Mr. Colman.

ture, if the action was continued, piping action would doubtless take place and later failure. The material difference in the percentage of pressure, Fig. 9, for the 3 and 4-ft. heads over the differences in percentage of pressure for the 1, 2, and 3-ft. heads, indicates the approach to the limit of the working value of S.

The writer purposely avoided the question of the effect of the sand coefficients and sheet-piling until he had disposed of the items of fundamental importance. Not that the effect of these coefficients is unimportant; but that, in experimental work, it follows rather than precedes the above.

In Table 8, by Mr. Elliott, the observed pressure for alluvial soil at various heads is stated to be zero. Doubtless if the experiments had been continued for a time sufficient for the pressure to become constant at the various points throughout the sand mass, quite different results would have been attained. It requires no argument to show that only an impervious or stratified foundation could give such a result.

Mr. Baldwin-Wiseman states that:

"The rate of interstitial flow and of loss of pressure are largely dependent on the material of the sand grains, on their angles * * * and on the relative homogeneity of the sand mass."

The writer was unsuccessful in his attempt to determine the rate of flow through the sand mass, as explained on page 1324.* He is of the opinion that the sand coefficients would have a decided influence on the quantity of water passing by interstitial flow beneath a structure. It does not follow, however, that the same influences materially alter the rate of loss of pressure throughout the porous material forming the base of a structure.

For the sake of demonstration, it will be supposed that the foundations of two similar dams are formed of layers of open pipes, and that these pipes lead from various points in front of the structure along paths of a form (elliptical or otherwise) approximating the flow lines, to points at various distances below the toe of the structure. The space between the pipes will be considered as impervious, and is represented by the sand grains themselves. The two structures are situated so that they have constant and equal heads, and so that the elevation of the tail-water is the same. To carry out the analogy, the pipes will be shorter and more concentrated close to the floor of the dam, to represent the shorter path of, and the greater concentration of, flow in that region. At depths below the base, they will be less in number, but each will be of greater length than the ones above. The number of pipes will decrease rapidly, but the length of individual pipes will increase rapidly with increased depth below the base of the structure. In both cases, the total area of opening will be the same.

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* *Proceedings*, Am. Soc. C. E., for August, 1915.

The only difference in the two structures is that the first is made up of a large number of small-sized pipes, as compared with the second. Mr. Colman.

It is very plain, then, that the second will pass more water than the first. However, in both cases, the total loss of head from above the dam to below it is used up from just in front of the pipe entrance to just beyond the pipe exit. It is made up of not more than three losses: the loss which occurs at the entrance to the pipe, the loss per foot of pipe throughout its length, and the loss at the exit from the pipe. All three are functions of head and length of flow; but, as different pipes have different lengths, the three losses vary from pipe to pipe. The velocity of flow in each pipe will adjust itself so that the total loss in one pipe will equal that in another in each structure, and also between structures. This total absorption of head is necessary, from the very nature of the problem, otherwise piping effect will occur.

The formula for the discharge through sharp-edged orifices is of the form, $Q = m A \sqrt{2 g h}$, or $V = m \sqrt{2 g h}$.* This last equation may be written in the form, $V = m \sqrt{2 g} \sqrt{H' - h''}$, where H' and h'' represent the heads just in front, and just back, of the pipe entrance, respectively. $H' - h''$ will represent the head consumed in entrance loss.

According to the Williams formula for the flow of water in pipes, the loss is $h_f = \frac{K V^n}{d^0} L$. The exit loss could be represented by a formula similar to that for entrance loss. All three equations are functions of H and L.

H, the total head, may be placed equal to the several losses, or $H = h$ entrance $+ h$ pipe $+ h$ exit. Substituting these values, we have:

$$H = \frac{V^2}{m\ 2\ g} + \frac{K\ V^n}{d^0} L + \frac{V^2}{m'\ 2\ g}.$$

As pointed out previously, the value of V, the velocity of flow, is very small for all practical cases; m and m' are constants, and depend on the angle, size, and shape of the opening; they vary but little, however, with size; g has the value 32.2; K is a constant; L, the length, is relatively large, and increases rapidly with the depth below the floor of the structure; and d, the diameter of the pipe, is very small.

Now, as V decreases, the fraction, $\frac{V^2}{m\ 2\ g}$, decreases; and for small values of V, it approximates 0. Then $H = \frac{K\ V^n}{d^0} L$. This expression states that H is expended at the rate of $\frac{K\ V^n}{d^0}$ per unit of length over the entire length, L, regardless of whether the pipe is rough or smooth.

* Chapter 6, "Mechanics of Engineering," by Irving P. Church, Assoc. Am. Soc. C. E.

Mr. Colman.

It is very plain that the values of K, V, and d depend on the sand analysis; but V is the result of the weight of K, d, and L, and takes a value such that the foregoing expression holds.

It would appear that the loss of head per foot of L, the upward pressure exerted against the floor, is not materially influenced by the porosity, effective size, and uniformity coefficient of a homogeneous sand foundation; but that Q, which is the product of V and the effective area of openings in the cross-section, is materially influenced.

In the foregoing demonstration, the writer uses the pipe analogy in an attempt to carry out and clarify his thoughts. The comparison has been briefly referred to by different writers, none of whom, however, to his knowledge, carries it through to a conclusion.

Attention might be called to the fact that this analogy is not quite parallel, in that the effective area of openings in the sand increases somewhat from the surface of the sand in the bottom of the reservoir to some point beyond the toe of the dam. This influence, then, would alter the value of V throughout the length of its course; it would increase its value at the entrance, cause it gradually to decrease throughout the length of flow, and decrease it at the exit. In the foregoing equation, the entrance loss would be increased, the loss of head per foot of pipe would have a gradually decreasing value throughout the length, L, and the exit loss would be decreased. This small secondary influence of a greater or less change of velocity, as between structures, can alone act to alter the form of the upward pressure curve.

Mr. Creager and others think that for a sand equally pervious at all points, the upward pressure on the base of a dam without cut-off approximates $\frac{H}{2}$, irrespective of the size or ratio of the head to the base length. Designers have used values for upward pressure ranging from zero to H over the entire base length, L. They also disagree as to the point of application of this upward pressure. Some have used $\frac{L}{3}$ as the distance from the heel to its center of gravity, and others have used values as high as $\frac{L}{3}$ from the toe. It would seem, the plotted curves and data make this point clear, as Professor King points out, that the upward pressure is somewhat less than $\frac{H\ L}{2}$, or:

$$P = 31\ H\ \ L.$$

It also shows that the point of application of this force is $\frac{L}{3}$ measured from the heel of the dam.

Turning to the condition of sheet-piling, the writer feels justified in stating that, in the case of Sand *A*, he had used reasonable precautions in placing the 1-in. lumber piling at the heel. The results were unsatisfactory. With Sand *B*, a single piece of sheet metal was in each case closely tacked to the box on the two sides and to the heel of the dam to form the sheet-piling. Mr. Colman.

It would seem that, as Mr. Travell points out, "As the sheet-piling was made longer, a decrease in pressure would naturally be expected". If the indicated data are influenced so markedly, as they appear to be, by very small leaks, surely it emphasizes the desirability of using an impervious cut-off wall instead of sheet-piling at the heel of the structure.

It is not suggested that the use of an impervious, comparatively shallow, cut-off wall will reduce the flow, as some of those who have discussed the paper seem to assume; but that it will greatly reduce the upward pressure on the floor. The safety of a structure does not depend on the quantity of water that may pass through the sand foundation, but on the velocity and pressure head that may reach the exit layers of sand and wash away those particles.

Such a cut-off wall would concentrate the flow lines at its bottom, where no piping or washing action could take place. These lines, after passing the base of the cut-off, would spread out fan-like through an angle approximating a quadrant. This action would mean a rapidly increasing area of effective cross-section and a correspondingly reduced velocity of flow, with the accompanying loss of head. By altering the direction of flow, its concentration, and the resulting velocity of flow and loss of pressure head, where no removal of particles can occur, the upward pressure on the base of the dam is materially decreased, and its safety is proportionately increased.

The writer wishes to emphasize the point that an impervious cut-off wall of moderate depth at the heel of a structure will have more beneficial results than any quantity of sheet-piling.

All seem to agree that sheet-piling at the toe of a structure, if used, should be loosely driven.

Mr. Wegmann cites the failure of the dam at Austin, Pa., to refute the use of a cut-off wall, such as just outlined. The cross-section of this structure was of such a form as might be used on any moderately sound rock foundation, and was not designed for a porous foundation. It seems to the writer that the failure of this structure, the foundations of which were of stratified shale and sandstone, does not reflect on the point at hand.

The writer firmly believes that the effect of ordinary driven sheet-piling, either of wood or steel, as a cut-off for pressure head, is practically zero. The use of long-length, steel, sheet-piling and anchor-

Mr. Colman. piles, similar to those cited by Mr. Oakes, in a low diversion weir, has come under his observation. In this case (the original head weir on the Tarlac Irrigation Project, Tarlac, Philippine Islands), with the foundation and weir complete, and with a head of perhaps one-fifth of that for which the structure was designed, piping action was going on. Needless to say, when a flood came, shortly afterward, the structure failed.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

THE HYDRAULIC JUMP, IN OPEN-CHANNEL FLOW AT HIGH VELOCITY

Discussion.*

By Messrs L. D. Cornish, Caleb Mills Saville, R. D. Johnson, and Karl R. Kennison.†

L. D. Cornish,‡ M. Am. Soc. C. E. (by letter).—This paper and the discussions thereon are extremely interesting, and form a valuable addition to the disseminated knowledge of hydraulics. The writer regrets that lack of time prevents him from preparing a satisfactory discussion, but the facts regarding two cases which he has observed will be submitted, and may be of interest in connection with Part 6 of the paper. Mr. Cornish.

Fig. 30 shows sections of two dams which are now in operation on the Kentucky River. Dam No. 12 was put into operation in 1908, and is founded on a laminated shale which, *in situ* or in large masses, was apparently hard and durable, although small pieces, when thoroughly dried out and subsequently immersed in water, would rapidly break up into a finely-divided condition like mud. During periods of high water the movable crest is lowered, and the water surface may be anywhere between the limits shown. As indicated by the profiles, the water is gradually eroding the shale, which had to be broken up by blasting during construction excavation, and the eroded material has formed a bar about 150 ft. below the dam. The surface of the bar consists of large pieces of shale, many of which are approximately 3 by 7 ft. and from 6 to 8 in. thick, and the entire bar has been formed by material eroded from just below the toe of the dam.

Dam No. 1, 4 miles above the point where the river empties into the Ohio, is typical of several other dams above it. It was originally

* Discussion of the paper by Karl R. Kennison, Assoc. M. Am. Soc. C. E., continued from January, 1916, *Proceedings*.

† Author's closure.

‡ Cincinnati, Ohio.

Mr. Cornish. a timber crib structure, built in 1844, and was capped with concrete as far as *B* in 1902. The water scoured out the river bed to a depth of 20 ft. at *D*, and undermined and carried away the crib and concrete cap as far back as *A*, for a width of 150 ft. In 1909 this damage was repaired by constructing the concrete-capped rip-rap fill and crib, since which date the erosion has ceased and fine material (*D E*) has been deposited below the crib. The approximate depth of this deposit is 12 ft., but it varies considerably during a season of frequent rises.

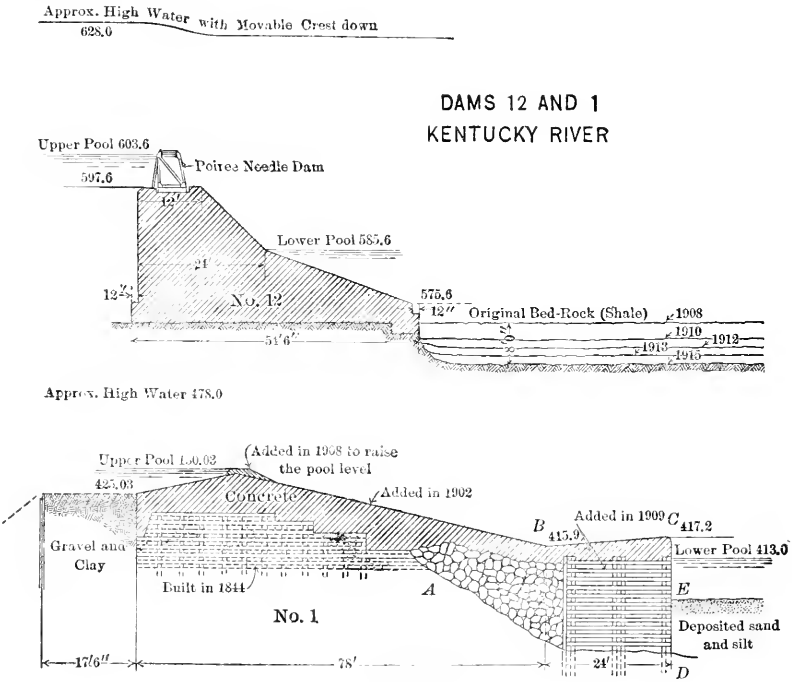


FIG. 30.

The absence of further erosion is attributed entirely to the apron, the inclined surface of which is typical of many movable and fixed dams of the Ohio River and its tributaries, and the construction of a similar crib-supported apron is proposed to prevent further erosion at Dam No. 12.

Mr. Saville. CALEB MILLS SAVILLE,* M. AM. SOC. C. E. (by letter).—The hydraulic principles involved in the phenomenon of the "Hydraulic Jump" are treated in a very able and thorough manner by the author,

* Hartford, Conn.

and his paper is a most valuable and timely contribution as so much engineering attention is being focused on "safety first" in the design of dams and appurtenant works. So clear has been the author's mathematical presentation of this subject that the most that remains is to bring forward examples of the nature of the hydraulic jump in special cases, and descriptions of the methods adopted to avoid danger in connection with this phenomenon. Mr. Saville.

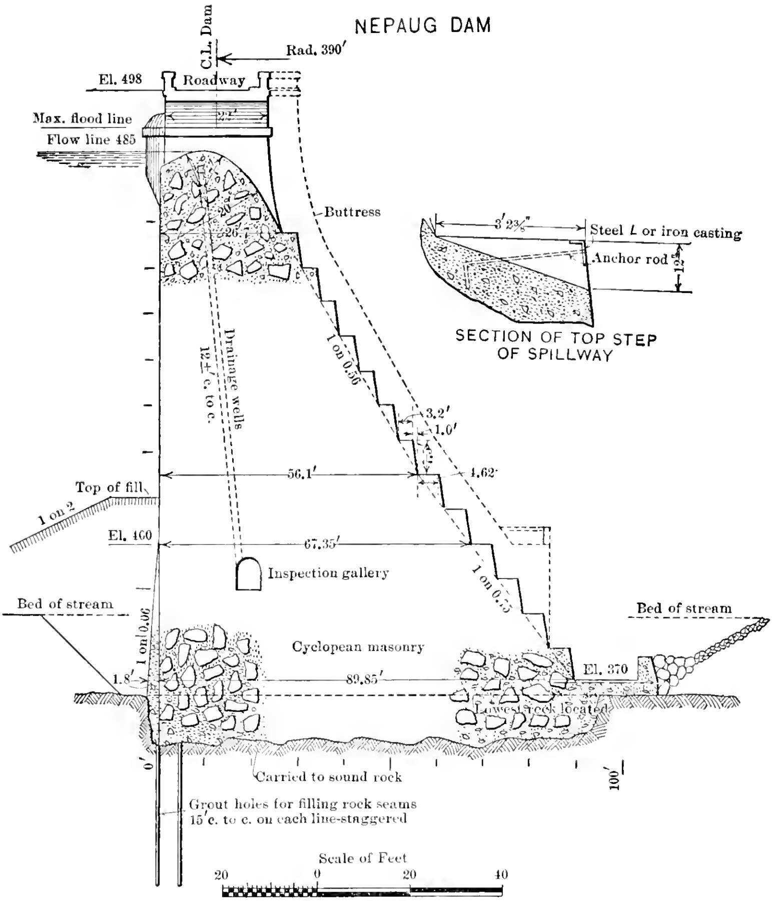
In his work on the additional water supply for the City of Hartford, Conn., the writer has recently had under his direction both the design and construction of several dams, which are of considerable magnitude and importance on account of local conditions. In connection with these, it is proposed to present some features of design and observation.

The Nepaug Dam is a cyclopean masonry structure, arched in plan, and closing a narrow valley. It has both overflow and non-overflow portions, the drop from maximum reservoir level to slack water below the dam being about 107 ft. Fig. 31 shows a maximum section of the overflow portion. This portion is about 180 ft. long, and particular attention was given to methods of breaking up the velocity which the water would acquire in falling over the dam and thus prevent it from doing damage at the down-stream base of the structure.

Two methods were used, both of which are indicated on the section. It is designed to break the smooth sheet of water passing over the ogee crest by forcing it to jump from step to step down the incline, instead of allowing it to glide smoothly to the bottom under full momentum. As an additional help, the first step, just below the crest portion, is to be alternately depressed and raised in sections about 5 ft. long. As a second line of defence, the discharged water will be received in a pool of dead water at the foot of the dam. The pool will be about 15 ft. deep, and will have a very massive concrete bottom with a baffle wall down stream. Both of these will be very heavily reinforced with steel, and the latter will be backed with large boulders. This provision is made in order to resist the force of the falling water and also the blow of any solid body that might come over the spillway. It is the expectation that the momentum of the water flowing over the spillway, on reaching the bottom, will be checked in the pool of dead water. Any energy that remains, however, will be expended, when the water is deflected back on itself by the obstruction of the baffle wall. During periods of considerable flow, the pool is expected to present a very turbulent appearance, but the water should flow away quietly, with no capacity for damage.

In the construction of the Nepaug and Phelps Brook Dams, connected with the same development—the latter an earth embankment with concrete core-wall and soil cut-off—it has been necessary to make

Mr. Saville. provision for the stream flow during construction. In both cases, rectangular wooden flumes were used at first. The wooden flume was continued at the Nepaug Dam, but at the Phelps Brook Dam it gave place after a time to the permanent concrete discharge conduit.



MAXIMUM SECTION OF OVERFLOW PORTION

FIG. 31.

During the construction of these dams there has been no exceedingly large run-off, but observations of the entrance conditions and hydraulic jump were made on several occasions when more than the ordinary quantity of water was flowing. The conditions which obtained are shown by Figs. 32 and 33. On Fig. 32 it is interesting to note the effect on the low flows caused by the slight projection of the stop-plank. Fig. 33 shows that the construction conditions at the inlet have a very marked effect on the character of the flow at the entrance. Mr. Saville.

In the case of a third structure—Richards Corner Dam—across a stream draining 62 sq. miles of territory having very quick run-off characteristics, a concrete conduit, having an inside width of 21 ft.,

PHELPS BROOK DAM CONDUIT
ENTRANCE LOSSES, WATER SLOPE, ETC.

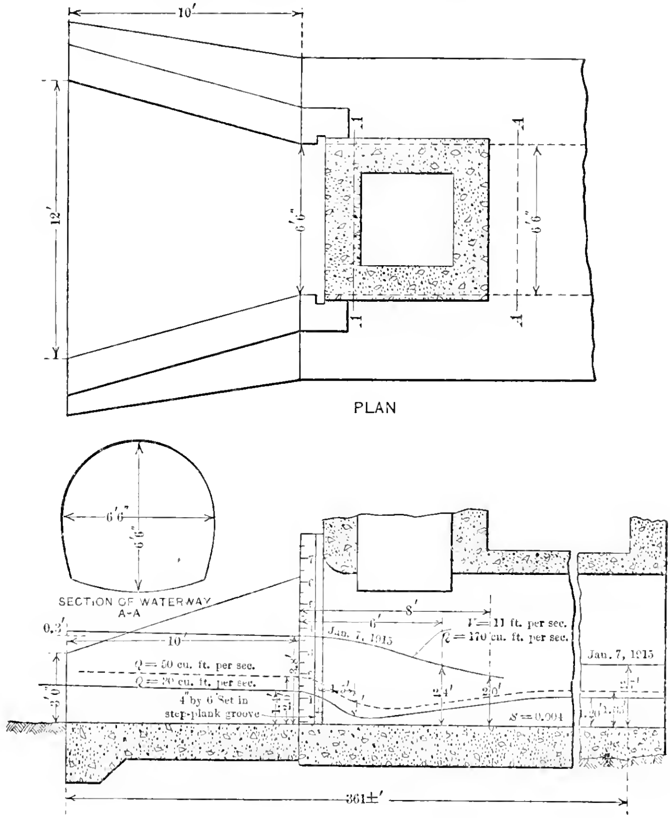


FIG. 32.

and founded on ledge, has been designed to divert the water during construction. Having in mind flood conditions, when there might be some difference in head between the surface of the water in the pond and that flowing in the conduit, the apron at the approach was arched and thickened considerably in order to resist the upward pressure due to this cause.

Mr. Saville. In the design of these dams acknowledgments are due to Messrs. Frederic P. Stearns and John R. Freeman, Members, Am. Soc. C. E., acting as consultants, for many valuable suggestions which were worked out and incorporated in the final plans.

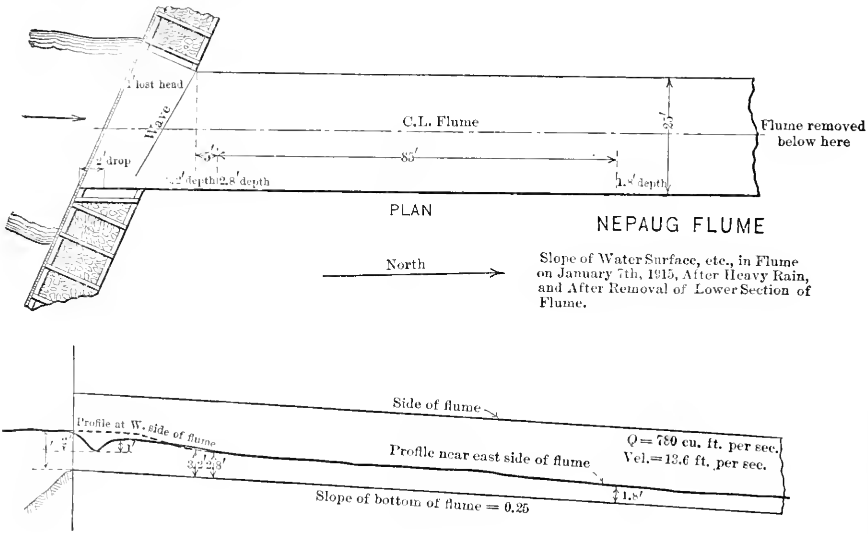


FIG. 33.

Mr. Johnson. R. D. JOHNSON,* Esq. (by letter).—Lately, there has been so much discussion of the mysteries of the hydraulic jump that the writer feels impelled to advance his own theory of the nature and magnitude of the losses involved, because he believes that the matter is capable of a more or less accurate analysis and should therefore be particularly interesting to those students of the subject who have searched in vain for an insight into Nature's method of determining a new water level following the so-called jump.

In recent publications of the Society appear many conflicting arguments, not only as to the possible magnitude of the losses, but even as to whether or not any loss exists—and it seems a proper time to lay down an exact method of determining these losses and to prove it by harmonizing the momentum and energy equations involved.

In the first place, it may be positively stated that, in a channel of uniform width, water cannot pass without loss from a lower to a higher level if the bottom remains flat. In other words, it may easily be proved essential that the lifting of the water surface be accompanied by a humping up of the bottom, if major eddy losses are to

* New York City. Previous discussion of this paper by Mr. Johnson was printed in December, 1915, *Proceedings*.

Mr. Johnson.

be eliminated. This will clearly appear from a brief mathematical discussion, but first it is desired to point out a fundamental law which pertains to the flow of water in a way perfectly analogous to its behavior with respect to solid bodies.

It is a well-known principle of impact that the sum of the momenta of two solid bodies cannot be altered by such bodies merely bumping into each other, and this is true, whether or not the impact results in a loss of energy; this law is commonly called the conservation of momentum, and is particularly interesting as applied to fluids because this persistence of the momentum law, in spite of energy or eddy losses, enables a comparison to be made between the momentum and energy equations which may disclose the inevitable eddy loss and determine the exact amount of it.

Now, in the case just referred to, of a change of water level to its higher alternative, theoretically without loss of energy, a comparison between the momentum and energy equations clearly shows the necessary existence of a force, F, which represents the tendency of the weir to slide up stream, and the necessary existence of the submerged weir is demonstrated in this, if in no other way, because the force cannot exist without the presence of the obstructing body.

FIG. 34.

There are many other interesting ways of demonstrating the same thing, but they will be passed over as not particularly pertinent to the matter in hand.

Referring to Fig. 34, the energy equation is as follows, if there is to be no eddy loss:

$$\frac{v_2^2 - v_1^2}{2g} = D - d \qquad \text{(1)}$$

The momentum equation, which always holds good, whether or not there are energy losses, for unit weight of fluid and unit width of flume, is as follows:

$$\frac{D^2 - d^2}{2} - F = \frac{Q}{g}(v_2 - v_1) \qquad \text{(2)}$$

which has been referred to by Dr. Unwin as a statement of the well-known physical law that force is equal to the rate of change of momentum.

It will be seen, from these two equations, remembering the relation, $d\ v_2 = D\ v_1 = Q$, that the value of F may be expressed in terms

Mr. Johnson. of other known quantities, and can never be zero, if Equation (1) holds good; therefore, Equation (1) cannot express the relation between the two depths and velocities unless a weir of proper form and dimensions is interposed.

Having now demonstrated the existence of the force, F, let us see what happens in the case of the hydraulic jump when there is no weir, and when, therefore, F must be zero.

It may be observed that by re-writing Equation (1) so as to include a certain friction or eddy loss, f, then the value of F in Equation (2) may become zero—and the new equations are:

$$\frac{v_2^2 - v_1^2}{2\,g} = D - d + f \qquad (3)$$

and,

$$\frac{D^2 - d^2}{2} = \frac{Q}{g}\,(v_2 - v_1) \qquad (4)$$

from which f may be determined as in the former case.

Now, although this statement of the matter really completes the whole story, it may be interesting to integrate the total eddy loss in a manner completely independent of Equation (3), and, having obtained its value, to show that its inclusion in Equation (3) makes this equation identical with Equation (4), thus demonstrating the whole matter *a fortiori*. To do this, let y be the variable between D and d, and, as we believe that eddies are accountable for the loss, let q be the total backward flow at any point where the depth is y. Also, let v be the mean of the horizontal components of flow in either direction. Then we may write,

$$v\,y = 2\,q + Q \qquad (5)$$

and, from the momentum principle,

$$\frac{y^2 - d^2}{2} = \frac{Q}{g}\,(v_2 - v) \qquad (6)$$

Solving $2\,q$ in terms of y, we have,

$$2\,q = \left(v_2 + \frac{g\,d^2}{2\,Q}\right) y - \frac{g\,y^3}{2\,Q} - Q \qquad (7)$$

Now, the power required to force the water, q, against the differential pressure, dy, is $q dy$; but, as the same quantity of water is returning on the other side of the eddy due to the same difference of head, dy, and under identical uniform conditions of impact, or heat losses, the total power required to keep these eddies in motion must be $2\,q dy$, and therefore the total lost power is expressed as

$$2\int_d^D q dy, \text{ and the friction head, } f = \frac{2}{Q}\int_d^D q dy.$$

Mr. Johnson.

Expressing q in terms of y, as above, and integrating we find,

$$f = \frac{D^2 - d^2}{2\,Q}\left(v_2 - \frac{g}{4\,Q}\,(D^2 - d^2)\right) - (D - d) \ldots\ldots\ldots (8)$$

and, if this is substituted in Equation (3) and the equation simplified as far as possible, we shall have Equation (4) as a result, thus harmonizing the equations of energy and momentum by recourse to a rational hypothesis of eddy loss.

Mr. Kennison.

KARL R. KENNISON,* ASSOC. M. AM. SOC. C. E. (by letter).—The writer is pleased to note the interest which this paper has aroused, and wishes to thank those who have contributed to the discussion. In order to answer some of the questions which have arisen to show more clearly the applicability of certain formulas which have been proposed for the height of the hydraulic jump, and to illustrate the extent of experimental knowledge on the subject, the writer has prepared the diagram, Fig. 35. The arrangement of this diagram was determined from the following considerations:

Diagram Showing Height of Hydraulic Jump in Smooth Rectangular Channels.—As has already been explained, there are evidently two "alternative stages" in every open channel, and in the hydraulic jump the water level rises from the lower to the upper. Hence, although the loss of head ordinarily accompanying the jump prevents the water level from reaching the same upper stage that existed before the jump occurred, nevertheless it appears that the height theoretically attainable and that actually reached should be directly related to each other. The diagram is plotted between these two variables: On the horizontal scale, $\frac{v_1}{\sqrt{g\,d_1}}$ is a function of the relative distance apart of the two alternative stages, expressed so as to be easily computed from the known velocity, v_1, and depth, d_1, before the jump; on the vertical scale, $\frac{d_2}{d_1}$ is the ratio of depth after the jump to depth before the jump. It is interesting to note that the more or less formidable looking formulas to be found in the discussions of this paper can, without exception, be expressed with comparative simplicity in terms of these variables, and are easily plotted on this diagram.

Let the "alternative stage ratio", $\frac{v_1}{\sqrt{g\,d_1}}$, be represented by S, and the "hydraulic jump ratio", $\frac{d_2}{d_1}$, by J. Then the formula representing a jump to the theoretic upper alternative stage, without any loss of head whatever, is

$$2J^2 - S^2\,J = S^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

* Providence, R. I.

Mr. Kennison.

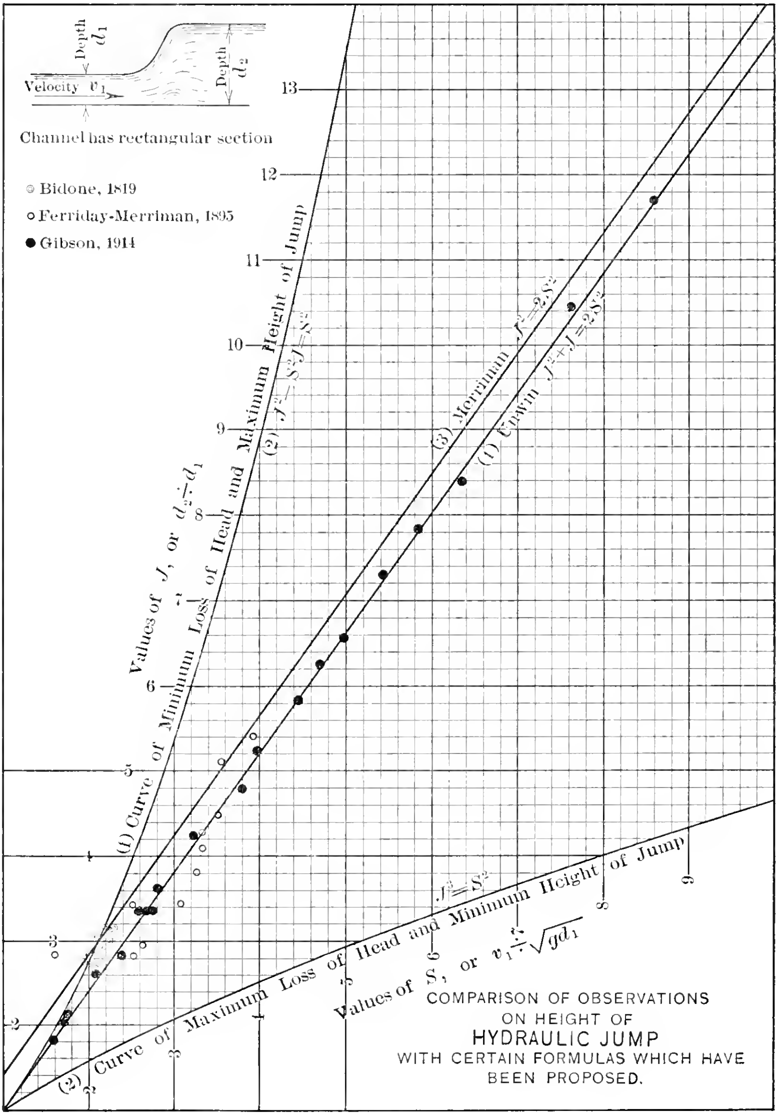


FIG. 35.

Mr. Kennison.

This formula, in its more complex form, was worked out in detail by Mr. Groat, on page 2507,* and by Mr. Johnson, on page 2673.† It is also identical with Professor Engel's formula, described by Mr. Andrews on page 2668.† In Fig. 35, this curve is labeled "Minimum Loss of Head and Maximum Height of Jump."

In direct contrast to this, the formula representing the jump to the "critical stage of maximum discharge under a given head" is

$$J^3 = S^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

In the diagram, this curve is labeled "Maximum Loss of Head and Minimum Height of Jump". Now, the only part of the diagram with which we are concerned is that lying between these two curves, as it is impossible for the jump to be higher than shown by Curve (1)‡ or lower than shown by Curve (2).

In Table 6 have been summarized some of the observations on the height of the hydraulic jump which have been called to the writer's attention. These have been plotted on Fig. 35. In general, these points appear to fall on a straight line drawn from the intersection of Curves (1) and (2). The vertical distance below Curve (1) corresponds to the loss of head occurring in the jump. Note that for small values of $\frac{v_1}{\sqrt{g\,d_1}}$, that is, when the two alternative stages are not far apart, the loss of head in the jump is relatively very small, as would naturally be expected. Practically all the earlier experiments, such as those of Bidone, were of this nature, and gave but little evidence as to what would happen with large values of $\frac{v_1}{\sqrt{g\,d_1}}$, as in the case of a spillway discharge. Mr. Robert Ferriday's experiments, the results of which Mr. Merriman has kindly put on record in his discussion of this paper, reached a value of 3.9 for $\frac{v_1}{\sqrt{g\,d_1}}$. Fig. 35 shows that the plotting of these results is not very uniform. One point falls quite a distance outside of Curve (1), an impossible result, which was noted also by Mr. Merriman.

The most remarkable tests are those by Professor Arnold H. Gibson referred to by Mr. Walker on page 2679.† One of the experiments was for a value of $\frac{v_1}{\sqrt{g\,d_1}}$ as high as 8.6. All these points come remarkably close to a single line, apparently straight, and falling

* *Proceedings*, Am. Soc. C. E., for November, 1915.

† *Proceedings*, Am. Soc. C. E., for December, 1915.

‡ The actual jump could be very slightly higher since, due to our convenient erroneous assumption of uniform distribution of velocity throughout the section, the actual total energy head in the stream is slightly greater than computed.

Mr. Kennison. rapidly away from Curve (1); that is, the loss of head in the jump increases rapidly as $\frac{v_1}{\sqrt{g\,d_1}}$ increases, or as the alternative stages draw apart from each other. Some idea of what these values of $\frac{v_1}{\sqrt{g\,d_1}}$ mean is obtained by noting that, for a flood of 5 ft. over a 20-ft. dam, $\frac{v_1}{\sqrt{g\,d_1}}$ = about 7; over a 25-ft. dam, about 8; and over a 30-ft. dam, about 9. Attention is called, later, to an observation by Mr. Ewald on $\frac{v_1}{\sqrt{g\,d_1}} = 12.5$.

TABLE 6.—Ratios, S and J,

Computed from Observations on Hydraulic Jumps.

(1) Observed mean velocity, v_1, in feet per second.	(2) Observed mean depth, d_1, in feet.	(3) Observed mean depth after jump, d_2, in feet.	(4) Alternative stage ratio, S: $v_1 \div \sqrt{g\,d_1}$.	(5) Hydraulic jump ratio, J: $d_2 \div d_1$.
Bidone's Observations; Series I to IV.*				
4.47	0.155	0.423	2.00	2.73
4.45	0.155	0.437	1.99	2.82
4.41	0.156	0.430	1.97	2.76
4.52	0.152	0.436	2.04	2.87
5.59	0.208	0.613	2.16	2.94
5.56	0.210	0.620	2.14	2.95
5.52	0.211	0.630	2.12	2.98
5.49	0.212	0.642	2.10	3.02
5.67	0.206	0.647	2.20	3.14
6.29	0.246	0.738	2.24	3.00
6.36	0.244	0.745	2.27	3.05
6.39	0.242	0.764	2.29	3.15
4.55	0.150	0.398	2.07	2.65
4.57	0.150	0.405	2.08	2.70
4.57	0.150	0.428	2.08	2.85
4.59	0.149	0.423	2.10	2.84
Ferriday's Observations; Series I to VII and IX to XII.†				
2.18	0.050	0.143	1.72	2.86
2.98	0.044	0.150	2.50	3.41
3.56	0.036	0.153	3.31	4.25
3.66	0.033	0.168	3.55	5.10
4.39	0.095	0.267	2.51	2.81
5.02	0.083	0.285	3.07	3.44
5.02	0.071	0.290	3.32	4.08
3.50	0.055	0.162	2.63	2.95
3.95	0.046	0.175	3.25	3.80
4.06	0.042	0.188	3.50	4.48
4.33	0.038	0.205	3.92	5.40

* *Transactions*, Royal Soc. of Turin, 1819, p. 21.

† *Engineering News*, 1895, Vol. 34, p. 28; also *Proceedings*, Am. Soc. C. E., for December, 1915, p. 2677.

TABLE 6.—(*Continued.*)

Mr. Kennison.

(1) Observed mean velocity, v_1, in feet per second.	(2) Observed mean depth, d_1, in feet.	(3) Observed mean depth after jump, d_2, in feet.	(4) Alternative stage ratio, S: $v_1 \div \sqrt{g\,d_1}$.	(5) Hydraulic jump ratio, J: $d_2 \div d_1$.
GIBSON'S OBSERVATIONS; SERIES A, B, AND C.*				
4.30	0.0735	0.265	2.79	3.61
5.82	0.0731	0.350	3.79	4.79
7.20	0.0730	0.455	4.69	6.23
8.33	0.0729	0.530	5.43	7.28
8.95	0.0728	0.570	5.85	7.83
9.74	0.0730	0.612	6.35	8.39
11.66	0.0728	0.760	7.62	10.44
13.12	0.0727	0.850	8.59	11.69
3.45	0.1465	0.267	1.59	1.82
5.68	0.1395	0.467	2.68	3.35
6.82	0.1390	0.587	3.22	4.22
8.39	0.1390	0.726	3.96	5.22
9.40	0.1390	0.808	4.44	5.81
10.53	0.1390	0.910	4.98	6.55
4.43	0.2075	0.419	1.71	2.02
4.53	0.2070	0.440	1.75	2.12
5.34	0.2048	0.530	2.08	2.59
6.09	0.2046	0.575	2.37	2.81
6.63	0.2040	0.678	2.58	3.32
7.05	0.2043	0.684	2.74	3.34
7.24	0.2043	0.735	2.82	3.59

* *Minutes of Proceedings*, Inst. C. E., Vol. CXCVII, p. 233. "The Formation of Standing Waves in an Open Stream," by Professor Arnold H. Gibson.

The diagram clearly shows the need of additional experiments with high values of $\frac{v_1}{\sqrt{g\,d_1}}$, and under a variety of conditions. The writer maintains that Professor Gibson's results, although very uniform among themselves, do not furnish sufficient evidence that the relative height of the jump will be the same under other conditions. In his experiments, which were carried on in a flume 3 ft. wide, observations were taken on the height of the tail-water necessary to bring the jump back close to a rectangular opening through which the water was being discharged along the bottom of the flume. Hence the discharge was the very steady discharge of an orifice, and not the free flow of an open channel such as Ferriday's. This may account for the remarkable uniformity of the observations.

Application of Hydraulic Jump Formulas.—In regard to the use of certain hydraulic jump formulas in the design of important structures for controlling the flow of water, Fig. 35

Mr. Kennison.

shows that the actual experiments which check these formulas are, for the most part, on small values of $\frac{v_1}{\sqrt{g\,d_1}}$, that is. under different conditions than obtain, for example, in the case of a high spillway dam. Mr. Merriman's formula, described in detail by Mr. Andrews on page 2667,* reduces to

$$J^2 = 2S^2 \quad (3)$$

and Professor Unwin's formula, described in detail by Mr. Andrews on page 2669,* reduces to

$$J^2 + J = 2S^2 \quad (4)$$

Fig. 35 shows that the Merriman formula gives values of $\frac{d_2}{d_1}$ greater than the Unwin formula by a nearly constant quantity, about 0.5. The Merriman curve crosses Curve (1) at the point, $\frac{v_1}{\sqrt{g\,d_1}} = 2.12$; hence, for values of $\frac{v_1}{\sqrt{g\,d_1}}$ less than about 2, it will give impossibly large values of the depth, d_2; and for values of $\frac{v_1}{\sqrt{g\,d_1}}$ equal to or a little greater than this, it should give correct results, especially if the jump occurs smoothly, with very little loss of head. Note the remarkable agreement between the Merriman formula and the Bidone experiments, in all of which the value of $\frac{v_1}{\sqrt{g\,d_1}}$ was nearly constant, from 2.0 to 2.3. The Unwin formula shows a remarkable agreement with the observations of Professor Gibson. Attention has been called in the paper and the discussions to the deduction of these formulas. It is hardly necessary to discuss them further. Note that the Unwin formula, which in its deduction does not define the loss of head in the jump, gives a height of jump less than the Merriman formula, which assumes a definite loss by "sudden expansion".

Regardless of the correctness or incorrectness† of the deduction of these formulas, Fig. 35 shows that, except for the less important lower values of $\frac{v_1}{\sqrt{g\,d_1}}$, they both give results which are remarkably close to the truth, judging from the scanty information at present available. Hence, if it were a question of predicting, as closely as

* *Proceedings*, Am. Soc. C. E., for December, 1915.

† The writer wishes to emphasize the statement that there can be no doubt that the original Merriman equation is in error. Mr. Andrews, in defending it, loses sight of the fact that Bernoulli's equation takes into account the retardation in velocity due to a rise in water surface.

possible, the height of jump in a given case, the writer would not hesitate to use these formulas, with modifications to fit the variation of the actual channel from the condition of a smooth rectangular flume. However, is it not more often a question of what is the least depth which must be maintained below the discharge, in order that there may be no doubt as to the occurrence of the jump? For such a purpose, and until more observations are available to check Professor Gibson's results, the writer would use greater depths than indicated by the formulas in question. If these depths are not attainable, are not such devices as the inexpensive Bassano Dam baffle piers, or Mr. Stearns' baffle wall, proper and reasonable means for taking the occurrence of the hydraulic jump out of the realm of uncertainty? Mr. Kennison.

Alternative Stages and Alternative Slopes.—Some questions have arisen in the discussion regarding the alternative stages described in the paper. It appears that at any point, in an open channel which is carrying a certain quantity of water under a certain head, there are two and only two surface levels or alternative stages at which the water can flow steadily. This conclusion has been checked by the thorough mathematical analysis of Mr. Groat. A vertical line drawn through his diagram, Fig. 14, shows at a glance the relative position of these two stages in channels of rectangular, and also parabolic, cross-section. Although, at any particular section, the position of the alternative stages is not dependent on channel slope, neither stage can be maintained indefinitely without the proper slope of channel bed, the lower high-velocity stage naturally requiring a steeper slope than the upper low-velocity stage. Mr. Johnson has discussed at some length the relation between these slopes, very appropriately called "alternative slopes". Take, for example, the case of a stream flowing swiftly at the lower stage over a channel bed of insufficient slope. The head is gradually used up by the friction under this high velocity. As the head decreases, the two alternative stages approach each other to within striking distance, when the surface jumps to the upper stage, which the channel slope is steep enough to maintain. Such a jump, formed on a line, V-shaped in plan, due mainly to the greater depth in the center of the stream, is not an uncommon sight.

Mr. Dunham has asked, since a negative root of an equation often has an unexpected and important meaning, what is the meaning of the root — 1.82 ft. which was discarded on page 1709* leaving only two depths, 9.58 ft. and 2.24 ft., corresponding to the two alternative stages. The negative root, in this case, refers merely to the lower alternative stage at a point where the channel has been depressed a distance equal to twice the depth represented by the negative root.

* *Proceedings*, Am. Soc. C. E., for September, 1915.

Mr. Kennison. For example, Figs. 4 to 9 show the two alternative stages, 9.58 ft. deep and 2.24 ft. deep, respectively, in the case of 50 cu. ft. per sec. flowing under a total head of 10 ft. Now, referring to Fig. 5, if Pond No. 2 is removed entirely, so that the water surface drops along the dotted line, as soon as a point is reached where the channel bed is 3.64 ft. below its original level, we have depth = 1.82 ft., velocity = $\sqrt{2\,g \times 11.82}$ = 27.5 ft per sec.; and, because the surface of the water is — 1.82 ft. above the original channel bed, this condition happens to satisfy the cubic equation.

Loss of Head in the Jump.—Both Mr. Merriman and Mr. Ewald have had exceptional opportunities for studying the hydraulic jump. They have suggested that there are possibly two types of jumps, the "true hydraulic jump" having a smooth surface throughout, instead of the turbulent profile shown in Fig. 11. From a study of Fig. 35, this contention seems plausible. For small values of $\frac{v_1}{\sqrt{g\,d_1}}$, that is, when the alternative stages are close together, the observations follow very close to Curve (1); the Bidone experiments, in particular, show very little loss of head, and such jumps as these must have occurred very smoothly. Mr. Ferriday's observation—that balls of putty, carried along the bottom of the flume, stopped dead just below the toe of the jump—appears to indicate that an eddy is formed in the bottom of the channel. In such cases as Mr. Merriman's "true hydraulic jump" it is possible that the main body of water flows up over this eddy to the upper stage very smoothly, with practically no disturbance or loss of head, except that in the eddy itself. If this is true, the effect of this eddy would be similar to that of a smooth concrete weir built up from the channel bed, which may explain Mr. Ewald's reference to the jump "forming within itself the controlling section". Referring again to Fig. 35: for all velocities higher than those corresponding to the Bidone observations the water is apparently unable to maintain this smooth rise, for there is a marked falling away from Curve (1). It appears that, although there may be a difference in the appearance of two jumps under the different conditions cited, nevertheless they are fundamentally the same phenomenon, namely, the passage from the lower to the upper alternative stage. In stating that the loss of head is not an inherent part of this phenomenon, the writer had reference to the same fact that was noted by Messrs. Merriman and Ewald, namely, that in some cases the loss of head is not in evidence, although in others it is large and unavoidable. Mr. Ewald's observation of the apparent adjustment of forces in certain jumps and the steady destruction of energy with a minimum of noise, reminding him of a smoothly running motor under full load, is particularly interesting. Additional observations may possibly show a decided drop or break in the curve of Fig. 35 when $\frac{v_1}{\sqrt{g\,d_1}}$ reaches a value of about 2.5, otherwise the conclusion would be that there is no marked difference in type between those jumps that destroy much energy and those that destroy but little. Mr. Kennison.

Mr. Ewald has developed a formula for the hydraulic jump based on an assumption of loss by "sudden expansion" from the point, d_1, to the point, d_y, in Fig. 28, and but little loss after the point, d_y, is reached. It appears that he bases this diagram and the conclusions therefrom on the suggestions of the writer in the paper. If so, these suggestions were misunderstood. The water is flowing at the lower stage at d_1 and at the upper stage at d_2; but, at intermediate points, such as d_y, the conditions of internal pressure are so disturbed that the writer would not attempt to apply the laws of open-channel flow. If Mr. Ewald had in mind a controlling section formed within the jump itself, such as referred to above, then d_y should have been measured, not from the channel bed, but from the top of this controlling section, and the depth and velocity at such a theoretic controlling section, where depth $= \frac{2}{3}$ head, would be a function solely of the quantity discharged per foot of width, and not of the depth, d_2. It seems doubtful if such a controlling section within the jump itself can be formed, except with low values of $\frac{v_1}{\sqrt{g\,d_1}}$.

Mr. Ewald quotes an interesting experiment on a model dam. The observations, reduced so as to be plotted on Fig. 35, are $\frac{d_2}{d_1} = 14.3$, and $\frac{v_1}{\sqrt{g\,d_1}} = 12.5$. Unfortunately, this point falls outside the limits of the diagram as it was originally prepared. It falls about 15% below the Unwin curve, possibly due to the fact that actual channel conditions as represented in the model caused the jump to occur at a lower depth of tail-water than would be the case in a smooth rectangular flume. It is hoped that additional observations will take note of the effect of rough channels, elevated buckets, baffle piers, etc., in reducing the height of tail-water necessary to insure a flow at the upper alternative stage.

Since his first discussion of this paper, Mr. Johnson has submitted a very interesting discussion of the theoretical losses involved in the hydraulic jump, concluding that the Unwin formula will give the correct height of jump in smooth rectangular channels. Mr. Johnson

Mr. Kennison. has apparently shown—what had not yet been made clear—that the Unwin formula, which was developed merely by considering the momenta before and after the jump, is thoroughly consistent in its derivation with an energy equation between velocity and pressure heads before and after the jump. He has shown that the Unwin formula contains in reality allowance for a definite loss of head, equivalent, say, to the total foot-pounds per second necessary to stop the backward flow, *B*, in an eddy such as shown in Fig. 36, plus an equal amount of power necessary to carry this flow ahead again, *C*, this eddy or eddies operating under a head equal to the rise in surface in the jump, and the quantity flowing in the eddies being such that the proper relation between static head and momentum is maintained, not only at the beginning and end of the jump, as in the Unwin formula, but throughout the jump, on the basis of static pressure being proportional to the depth. The writer does not assent to this last assumption, as one would expect the conditions of internal pressure to be more or less disturbed within the jump itself. Nevertheless, the remarkable agreement of the Unwin formula with actual observations is clearly shown by Fig. 35.

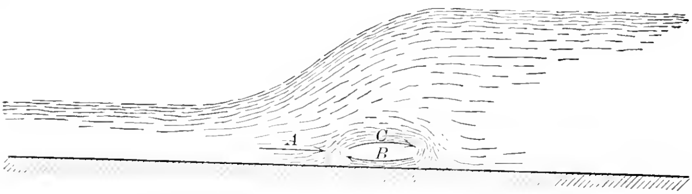


FIG. 36.

Mr. Johnson has not confined his losses to a single distinct eddy as shown at *B, C,* this Fig. 36 being more or less diagrammatic, to assist in discussing Mr. Johnson's theory. It also illustrates the foregoing reference to the jump forming within itself the controlling section, although, under high velocities, the loss probably occurs in many small eddies. Note that Mr. Ewald states: Pitot tube tests show that the quantity of water undergoing actual movement up stream is relatively small. Details of such tests are not given.

The total horizontal force, *A*, expended on the eddies is essential to the jump, as Mr. Johnson states, and is a measure of the loss of head in the jump; and, if this eddy was replaced by a smooth weir, no loss of head would occur, because, as Mr. Johnson clearly shows, the fastening of the weir to the channel bed keeps it from sliding up stream and obviates the necessity of the force, *A*.

Although the losses in the hydraulic jump under high velocities can be studied satisfactorily only by experimental observation, a reasonably correct theory as the basis for such studies is of great value.

Mr. Johnson's theory seems to be sounder than the few others which have been proposed, and is in excellent agreement with the actual observations now available. Mr. Kennison.

The Hydraulic Jump in Dam Design.—On account of the practical importance of the hydraulic jump in the design of spillway dams, this phase of the matter has received considerable attention in the discussions. The writer is indebted to Messrs. F. P. Stearns, C. M. Saville, L. D. Cornish, H. B. Muckleston, and E. W. Bush for the information which they have given, based on knowledge of actual conditions at important structures. Among other things, Mr. Stearns has called attention to a condition which is often overlooked, namely, the tendency of a concrete apron, from which the tail-water has been pushed down stream, to be forced upward by the excess pressure beneath it. Certain designs with which the writer has been connected have contained vent holes up through the concrete and inclined down stream, so that a slight suction would be produced to relieve the upward pressure under it.

The writer has already called attention in the paper to the destructive force of a spillway discharge. At seams in the rock foundation, the high velocity of the water is converted into pressure capable of tearing loose large masses of rock. It appears that this "Pitot tube action" is especially likely to erode rock which lies in horizontal strata. Mr. Cornish has given an excellent illustration of this in Fig. 30, and the erosion shown cannot be ascribed to the shape of the dam section. The writer has known of a similar case where horizontally stratified limestone was torn up, leaving a hole very similar to that shown below Dam No. 12 in Fig. 30. One piece of this limestone which was washed down stream weighed more than 20 tons. The erosion occurred close up to the toe of the dam, although the bucket was curved so as to deflect the discharge to an approximately horizontal direction.

The section of the Nepaug Dam shown in Fig. 31 involves noteworthy features, and the effect of the stepped face in preventing erosion of the boulder stream bed will be awaited with interest.

One important reason for knowing whether or not the flood height of tail-water is more than sufficient to cause the hydraulic jump, is this: If it is amply sufficient, then the back pressure of tail-water against the down-stream face of the dam may be counted on in computing the stability of the structure. If it is not sufficient, then none of this pressure above the bucket can be counted on, the only back pressure on the dam being the weight of the sheet of water and the reaction due to its deflection into a horizontal direction as it leaves the toe.

Mr. Kennison.

The hydraulic jump is indirectly connected with many other features in the design of works for controlling the flow of water, but the writer will not venture farther from the announced purpose of the paper, which was mainly "to call attention to the existence of the two 'alternative stages' in open-channel flow, and * * * to identify the 'hydraulic jump' as the passage from the lower to the upper stage."

In conclusion, the writer again thanks those who have contributed to the discussion, and hopes that additional observations will throw more light on the nature and extent of the energy losses occurring in the hydraulic jump.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

COHESION IN EARTH: THE NEED FOR COMPREHENSIVE EXPERIMENTATION TO DETERMINE THE COEFFICIENTS OF COHESION

Discussion.*

By Clifford Richardson, M. Am. Soc. C. E.

Clifford Richardson,† M. Am. Soc. C. E. (by letter).—The writer has examined this paper with some interest, and requests the author to define "cohesion" in the sense that the word is used therein. Does this term denote "the state in which, or the force by which, the molecules of the same material are bound together, so as to form a continuous homogeneous mass", as defined by the Century Dictionary? or is it used to denote merely the sticking together of particles by natural attraction, without, necessarily, involving the entire homogeneity of the material, in which case the question of surfaces and films is involved? It is the writer's idea that the stability of earth and soil is more satisfactorily explained by considering them as a mixture of fine particles possessing a large area of surface to which water may or does adhere, forming a system of two phases which should be studied from the point of view of modern physical chemistry. With an increase of fineness of any material, the surface areas of these particles likewise increase to an enormous extent, and this has very great influence over its physical character. Mr. Richardson.

The writer has shown‡ that the surface area represented by 1 gramme of sand of uniform size increases from 15 sq. cm. for a

* This discussion (of the paper by William Cain, M. Am. Soc. C. E., published in December, 1915, *Proceedings*, and presented at the meeting of February 2d, 1916), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† New York City.

‡ In his book "The Modern Asphalt Pavement", 2d ed., p. 358.

Mr. Richardson. material which will pass a 10-mesh sieve up to 9 056 sq. cm. for material so fine that it does not settle out of water after agitation in less than 16 hours. The data to which reference is made are as follows:

"ONE GRAM OF SAND OF UNIFORM SIZE CONTAINS

" Mesh Sieve.	Millimeter.	Particles.	Square Centimeters.
10	1.50	212.8	15.0
20	.84	1 215.9	27.0
30	.58	3 693.6	39.4
40	.40	11 261.0	56.6
50	.26	41 005.0	87.1
80	.20	90 066.0	113.2
100	.13	328 032.0	174.2
200	.08	1 407 620.0	283.0
1 minute	.05	5 643 700.0	442.4
30 minutes	.025	46 124 900.0	905.7
2 hours	.0075	6 800 990 000.0	1 201.6
16 hours	.0025	46 124 900 000.0	9 056.6"

It will be seen, therefore, that the stability of any earth fill depends on the size of the particles and the area which their surfaces present, when considered in relation to a liquid phase, water.

It will be of interest, in connection with this subject, to study the principles of the modern chemistry of colloids which relate to surfaces and films.* These principles have a large bearing on the subject treated in this paper.

* Outlined in a most satisfactory manner in a book entitled "The Chemistry of Colloids and Some Technical Applications", by W. W. Taylor.

MEMOIRS OF DECEASED MEMBERS

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

LOOMIS EATON CHAPIN, M. Am. Soc. C. E.*

DIED JUNE 18TH, 1915.

Loomis Eaton Chapin, son of Zerah Chapin and Lucy (Starkweather) Chapin, was born on May 7th, 1858, in Weathersfield, Ill. His father was a miller operating what in those days was considered an extensive flour mill. During his childhood, his parents removed to Kewanee, Ill., and there he received his early education in the public schools and high school. Later, he entered the University of Michigan, and was graduated in the Class of 1883 in the Department of Civil Engineering.

As is frequently true in the early experience of many engineers, Mr. Chapin worked during the school vacations in various capacities and on miscellaneous engineering work. Thus, he was employed on the surveys of the Toledo, Ann Arbor, and Grand Trunk Railway; on the Wheeling and Lake Erie Railroad Bridge over the Maumee River; later, by the Wheeling and Lake Erie Bridge Company on similar work at Toledo; and then by the Toledo Belt Railway Company on surveys.

On graduation, in May, 1883, Mr. Chapin entered the employ of the City of Toledo, Ohio, as Assistant Engineer, which position he held until 1887. During this time he had charge of the construction of many important public works and street improvements, among which was the Cherry Street Bridge over the Maumee River.

From 1887 to September, 1891, he was Associate Engineer with J. D. Cook, Hydraulic Engineer, and was engaged on the design and superintendence of water-works and sewerage systems in many cities and towns throughout Ohio, Indiana, and Michigan. The experience and development obtained under Mr. Cook, who was an old-fashioned, dignified, courteous engineer, doing important work at that time, was excellent for the young men who had opportunity to be in his office. Undoubtedly, the excellent qualities of Mr. Chapin's later life reflected the training thus obtained, and served during the progressive growth of Toledo, Ohio, when many important engineering problems were solved. Among these, that which stands out pre-eminently was the

* Memoir prepared by Morris Knowles, M. Am. Soc. C. E.

construction of the sewage treatment works in which chemical precipitation was utilized. This was at a time when the treatment of sewage was just coming into vogue, and the necessity of treating these obnoxious human wastes, in order that nuisances might be avoided and the spread of infectious disease prevented, was just beginning to be realized. The chemical precipitation works, following closely after the completion of the similar work at Worcester, Mass., were based on the investigations and report of Samuel M. Gray, M. Am. Soc. C. E., Consulting Engineer, of Providence, R. I., and were built under Mr. Chapin's supervision. This experience gave him an early insight into the problems of sewage disposal, and caused him to be called upon as a consultant in many similar problems in other cities in the Middle West.

At about this time, he engaged in consulting engineering practice, with an office in Canton, Ohio. From 1902 to 1907, he was associated with Morris Knowles, M. Am. Soc. C. E. During this period an office in Pittsburgh, Pa., was opened, and, after 1907, this, as well as the office in Canton, Ohio, was continued by Mr. Chapin to the time of his death. During this time, many water-works systems, purification plants, sewerage systems, and sewage treatment plants were designed and erected under Mr. Chapin's direction, and his reports on municipal improvements are to be found in the files of many cities and towns in the Allegheny Mountains and throughout the Middle States.

Later, Mr. Chapin paid a great deal of attention to water-works valuation, particularly referring to rate cases, for clients many of whom he had previously served in other ways. He also built several industrial and manufacturing works for corporations and groups of mining and operating companies, and was the regular advisor of many of his clients. At the time of his death he was continuous Consulting Engineer for the Beaver Valley Water Company, the North Michigan Water Company, and several other companies, as well as some municipalities.

Mr. Chapin was of a genial temperament and was a companion full of fellowship. He was an indefatigable worker, even to the exhaustion of his own strength and resources, but ever had the sunny point of view, and was universally liked by clients and brother engineers.

He was married on October 13th, 1886, to Elizabeth Hadley, of Ann Arbor, Mich., who survives him, together with one son, Robert Hadley, and two daughters, Persis Louise and Elizabeth Loomis.

Mr. Chapin was elected a Junior of the American Society of Civil Engineers on December 3d, 1884; an Associate Member on September 7th, 1892; and a Member on November 4th, 1896.

EDWARD MACAULAY HARTRICK, M. Am. Soc. C. E.*

Died August 17th, 1915.

Edward Macaulay Hartrick was born in Belfast, Ireland, on January 11th, 1847. In his youth he suffered from acute asthma, and could not sleep unless he was propped up in bed. His doctors having ordered a sea voyage, he went as midshipman in the Green Company (British East India Company) service from London. He served there about three years, and returned home completely cured.

He was educated and received his degree in Dublin University, being graduated second in a class of twenty-nine and a special, in 1868. He was engaged in the Engineering Department of the Midland Great Western Railway of Ireland at some time either before or after graduation.

In 1869 Mr. Hartrick came to the United States and joined his brother at Fishkill Village, N. Y., in work on the Connecticut Western Railway. This lasted until 1870 or 1871. He then moved to Port Jervis, thence to Pittsburgh in 1871, and to Chicago in 1872, at each of which places he was engaged on railroad work. He served during this time with the Marietta and Pittsburg Railroad; the Shephang Valley Railroad; on the Suspension Bridge over the Delaware River at Port Jervis; the Milford, Matamoras Railroad, of Pennsylvania; and the Pittsburgh, Cincinnati and St. Louis Railroad.

Some time after 1872 he moved to Texas, and was engaged on the location and construction of the Texas and Pacific Railway, and from this time forward he spent his life in that State.

From about 1880 to about 1886 Mr. Hartrick was City Engineer of Galveston, Tex. Then he was in private practice for about a year, and in 1887 entered the service of the United States Engineer Department as Sextant Observer, and was engaged in making various surveys. From that date until his death, 28 years of continuous service, he was with that Department. In 1888 he was placed in charge of the Galveston Bay Ship Channel work, now known as the Houston Ship Channel. In 1890, on the resignation of H. C. Ripley, M. Am. Soc. C. E., he was made Principal Assistant Engineer, with immediate charge of the improvement of Galveston Harbor, the most important work in that Engineer District at the time. On the completion of the present jetties at that harbor, in 1898, he continued to act as Principal Assistant Engineer on all the work in the District. In 1912, various ocular troubles rendering further office work impossible, he was transferred

* Memoir prepared by C. S. Riché, M. Am. Soc. C. E., and N. T. Blackburn, U. S. Asst. Engr., U. S. Engr. Office, Galveston, Tex.

to the charge of the Houston Ship Channel work. On August 16th and 17th, 1915, while at his post of duty on the quarter boat at Morgan Point, a severe tropical hurricane passed over that section of the Gulf Coast, the quarter boat was wrecked, and he was drowned.

Mr. Hartrick was a member of Harmony Lodge No. 6, F. & A. M., San Felipe de Austin Chapter No. 1, Royal Arch Masons, and Texas Consistory No. 1, Scottish Rite Masons, all of Galveston. On October 18th, 1905, he was elected to the 33d honorary degree. He was also a member of El Mina Temple, A. A. O. N. M. S. He was a member of the Episcopal Church.

Mr. Hartrick was married to Miss Mary McClellan, of Galveston, Tex., and survived his wife by about 13 years. They had no children.

His death was directly due to his sense of duty. Knowing that the hurricane was coming, he left a place of safety at Galveston, went past his home at Dickinson, and took his station on his boat at his official place. Here he remained until the end. Loyal and steadfast in life, in death unafraid, he has passed to his reward.

Mr. Hartrick was elected a Member of the American Society of Civil Engineers on February 1st, 1899.

FRANCIS WINTHROP SCARBOROUGH, M. Am. Soc. C. E.*

Died December 24th, 1915.

Francis Winthrop Scarborough was born in Cincinnati, Ohio, on September 6th, 1865. He was graduated from the Rensselaer Polytechnic Institute in 1888, and immediately entered the service of the Chesapeake and Ohio Railway Company as an Assistant Engineer. In July, 1891, he was appointed Division Engineer in charge of maintenance on various Divisions and remained in this position until April, 1899, when he was made Engineer of Bridges and Signals. In this capacity, he had full charge of the design and construction of all bridges and signal plants for the Company.

In January, 1902, he was appointed Chief Engineer of Maintenance of Way and Structures, with jurisdiction over all the lines operated by the Company, which position he held until he resigned in 1908. During this period, Mr. Scarborough had charge of the construction of the Richmond Viaduct and Terminal, one of the greatest railroad improvements executed in that section of the country, the general plan of which was initiated by Harry Frazier, M. Am. Soc. C. E.

After his resignation in 1908, Mr. Scarborough became actively engaged in the operation of coal mines in the New River region of the Chesapeake and Ohio Railway, with headquarters at McDonald,

* Memoir prepared by Messrs. C. J. Roelker and James P. Nelson, Richmond, Va.

W. Va. Later, he returned to Richmond, Va., where he practiced his profession as a Consulting Engineer. At the time of his death, he was President of the Virginia Bonded Warehouse Corporation, and was also engaged in the development of plans for water and sewerage systems for Charlottesville, Va.

As an officer of the Chesapeake and Ohio Railway Company, Mr. Scarborough commanded the confidence of the executives, and conducted his organization with marked ability. Added to his scientific attainments, which were notable, and to his fine sense of organization, which was of a high order, was the unique personal gift of eliciting the complete loyalty, and even the affection, of his subordinates. Tireless himself as a worker, he imbued others with a like spirit. Thus, he became a power on that road.

Mr. Scarborough was peculiarly fearless in his mental characteristics. He was always reasonable and open to conviction, yet, when he saw what seemed to him to be the truth, he maintained his position with the utmost firmness and with unfailing courtesy. He was thoroughly fitted for the high calling of his choice; fitted by Nature for any high calling.

The record of his life is brief, but to those who knew him and loved him, that record would be incomplete—even barren of the truth—did it not contain some expression of the love that went with him wherever he met with his fellow men.

His opinions were sought, and were the guides for men handling important matters. All of this is stated of the accomplished engineer, the able leader and governor of men, the counsellor in his Profession; but those who knew him as the man think of him as the large-hearted, generous, loyal, beloved friend; as the unassuming, open-handed, delightful companion, ever speaking of all men only that which was kind, with a soul devoid of malice toward any man.

The last months of Mr. Scarborough's life were clouded by sickness, but even then his spirit never lost its brightness, his courage never failed. As men should, he met his last earthly summons, and when the message came, made answer without fear. He died in New York City on December 24th, 1915.

Mr. Scarborough was a member of the Westmoreland and Commonwealth Clubs, and of the Country Club of Virginia. He served two years in the Commonwealth Club as Vice-President. He was also a member of the American Society of Mechanical Engineers, the American Institute of Mining Engineers, the American Society for Testing Materials, the American Railway Engineering Association, and the Delta Phi Fraternity.

Mr. Scarborough was elected a Junior of the American Society of Civil Engineers on September 3d, 1890; an Associate Member on March 6th, 1895; and a Member on February 2d, 1904.

JOEL HERBERT SHEDD, M. Am. Soc. C. E.*

Died November 27th, 1915.

By the death of J. Herbert Shedd, the Engineering Profession loses a man of distinction. Early in life, Mr. Shedd established a reputation as an engineer of superior ability in hydraulic and sanitary work. He was born on May 31st, 1834, and began his professional life in 1850, when he entered, as a student for three years, the engineering office of Messrs. T. and J. Doane, at Charlestown, Mass. Before the three years were completed he was given charge of important railroad work in Indiana. In 1856 he opened an office in Boston for the general practice of his profession, but specialized in hydraulics and sanitary engineering.

Mr. Shedd retained his office in Boston for forty years. Many engineers, in practice to-day, scattered over our country, received part of their training under him. When he decided to give his attention to the designing and construction of the Providence Water-Works, he left the Boston office in charge of his partner, Mr. Edward Sawyer, at which time sixteen young men were studying engineering there. This was not long before the Institute of Technology was established.

In selecting hydraulics for his special branch of professional work, Mr. Shedd made no mistake. His aptitude and ability in this line were soon recognized by public officials. As early as 1860 he was appointed by Gov. Andrew, of Massachusetts, as Commissioner on the Concord and Sudbury Rivers. In June, 1876, on the establishment of a Board of Harbor Commissioners for the State of Rhode Island, Mr. Shedd was appointed a member, was elected Chairman, and held that position continuously until the end of his life. He was Commissioner from the State of Rhode Island to the Paris Exposition in 1878. Later, he was engaged in other important service for the State: as Chairman of the Rhode Island Section of the Interstate Commission to establish the boundary line between the States of Rhode Island and Connecticut, about 1885; as Chairman of the Rhode Island Section of the Interstate Commission to establish encroachment lines in the Paweatuck River, about 1887; as a member of a Commission to inquire into the "Desirability, Necessity, and Cost of Either Making Changes in the Present Stone Bridge across Sakonnet River, or of Erecting a New Structure", 1902 to 1904, and as a member of a Commission for a new bridge, 1904 to 1910.

Among all the works devised and built by Mr. Shedd, those at Providence are best known. In the opening statement of his report to the "Committee of the City Council on a Supply of Pure Water

* Memoir prepared by O. Perry Sarle, M. Am. Soc. C. E.

for the City of Providence" of October, 1868, he has recorded his engagement in the following words:

"In the month of October, 1868, I was called upon by you to make a professional examination of all possible sources of supply, with a distinct understanding that this examination should be entirely independent of all previous investigations and reports. To this end I was kept in ignorance of what had been done in the past, and you have carefully refrained from giving me your impressions, if any you have, for or against any particular plan. I have thus been left free to consider the various possible plans in purely scientific light, without personal prejudice from any source."

This Committee, in its statement transmitting his report to the City Council, says:

"Mr. J. Herbert Shedd of Boston, an engineer of extensive reputation and business in Massachusetts, has served us faithfully. He has not only brought scientific attainments to bear upon the great question, but has made himself so familiar with our city and its needs in this regard as to become to all intents a citizen, except in prejudices."

In 1874, when the Providence Water-Works were nearing completion, on February 24th, the *Providence Journal* says, in its editorial columns:

"As the official term of the Board of Water Commissioners expires this week, the present has seemed to us a fitting time to review their work and sum up the result of their labors, * * *." "Desiring that the examination of our water-works and the resulting report for the *Journal* should not only be thorough, intelligent and comprehensive, but also be absolutely unbiased and impartial, we requested aid of the Hon. William Aspinwall, of Brookline, Mass., a member of the Water Board of that town, and a gentleman admirably qualified by cultivation, experience and observation in this and other countries, to pass judgment upon works of this description, and whose high character debars any suspicion of partiality or prejudice."

Mr. Aspinwall, in his report, printed in the *Journal* of the same date as the foregoing editorial, refers to the Chief Engineer in the following language:

"The Commissioners, with all their intelligence, faithfulness, and diligence, could never have reached the results attained had they not been so fortunate in their selection of a Chief Engineer.

"When Mr. Shedd first came to the work of the city, in 1866, to make the preliminary examinations reported in 1868, he brought with him, although still quite a young man, a most enviable reputation for a rare combination of the qualities essential to the attainment of the first rank in his profession. He already stood among the first engineers in Massachusetts for theoretical and practical knowledge of his business, as well as for an enthusiastic love for it. He was, besides, distinguished for his great executive ability and powers of systematic arrangement, and lastly for his perfect truthfulness and incorruptible integrity. This well earned reputation, I am happy to learn, has been fully sustained in his dealings with the people of Providence, and is cordially admitted, even by those who differ from him in opinion. The Chief Engineer has been the inventing and suggesting brain, as well as the strong right arm which has aided the Commissioners in deciding and then in executing the plans, first for the water-works and then for the sewers of Providence. Everything has passed under his supervision, and much if not most of the system which is so conspicuous in all the executive departments is due in great measure to him."

While Chief Engineer of the water-works Mr. Shedd designed and partly built the sewerage system in Providence. On retirement from this work he entered upon private practice in Providence, but returned to the city as City Engineer in 1890, which position he held for seven years. He also remained with the city for the two years next following this engagement, as Consulting Engineer, when the sewerage works were substantially completed.

His private practice succeeding his service with the City of Providence brought to him numerous water-works and sewerage plants to be investigated and developed. His knowledge and practice in the field of stream flow, and his general experience in hydraulics, led to work with reference to damages caused by the diversion of water for public supplies, which, from about this time forward, constituted a very important part of his professional practice. Some of the notable cases for which he did much important and successful expert work were those against the City of Pawtucket, R. I., for the diversion of the waters of Abbotts Run; cases against the City of Worcester, Mass., for the diversions of Tatnuck and Kettle Brooks; cases against the City of Woonsocket, R. I., for the diversion of the waters of Crook Falls Brook; cases against the Warwick and Coventry Water Company, for the taking of Carrs Pond; cases involved by the establishment of the Wachusett Reservoir, in Massachusetts, and numerous others in this same class involving damages of a similar nature.

His knowledge of stream flow caused a demand on his skill for the purpose of fixing responsibility for failure of works to withstand safely the discharge of streams in flood time. Among his commissions in this line is notably the breaking of the dam of the Diamond Hill Reservoir, in the great freshet of February, 1886, which caused extensive damage in the valley of Abbotts Run.

His practice in water-power work involved the examination of streams and catchment areas, the estimation of the power of streams, and the design and development of water-power plants. He made the complete study and development at Rumford Falls, Me., which power was entirely unimproved when he began work thereon.

Mr. Shedd was commissioned by the Norwich Water Power Company, at Norwich, Conn., to determine the quantities of water used by the several mills on the canal, and to establish a system for measuring the water. This commission was carried out, and the system established has been in use since about 1888. The charges for water used in the several mills are based on the measurements obtained by the use of this system. He also made similar investigations for the Union Water Power Company, at Lewiston, Me., and for the canal at Windsor Locks, Conn.

Although Mr. Shedd was not a prolific writer, he contributed much valuable literature on engineering subjects in the form of reports, some of which have been regarded as classics. He wrote the section on Rain and Drainage in French's "Farm Drainage", 1859, and the report on the Ventilation of Representative Hall of the State House in Boston, 1865. In 1880 he was appointed a member of a Committee of the American Society of Civil Engineers with reference to fixing a "Uniform System for Tests of Cements". He addressed the American Paper and Pulp Association in February, 1889, at its annual meeting in New York, on the subject of "Application of the Principles of Water Storage in New England Rivers". In recognition of his literary and scientific attainments, Brown University, in 1894, conferred upon him the honorary degree of A. M. For many years he was a member of the Visiting Committee to the Mechanical Engineering Department of Brown University.

Mr. Shedd always took much interest in the solution of problems and the design of devices for meeting cases which were out of the line of the ordinary development of work. He did not, however, make many attempts to secure his inventions by patents. He devised the Shedd water meter, which he patented. This proved to be a most excellent device, but was not developed commercially owing to the greater attraction of his professional life with which he was fully occupied. He was one of the patentees of an automatic flash-board, which was put in service at the lower dam on the Quinebaug River, near Taffts, Conn., about sixteen years ago, where it has given excellent service.

The last fifteen years of his life were largely devoted to consulting and expert service. His broad experience in his chosen field developed a demand for his opinions relating to valuations of water-works and water-power properties, and the value of water, to an extent rarely found in any one man's career. As an expert witness in contested cases, he has rarely been equalled.

In going over this brief sketch of a very busy life it is to be noted that very early, almost at the beginning, he had inspired in those with whom he came in contact a firm belief in his honor and integrity, and that all through his professional career of nearly sixty-six years these features of his character were constantly maintained, this maintenance being shown by the importance and magnitude of the works and commissions with which he was entrusted. There is an echo of the same high regard in a recent letter, in which it is said:

"We both had a great personal liking for Mr. Shedd, and were on most friendly and cordial terms with him, and the more we knew him the more we respected and admired him. He was open and frank, and was incapable of deception. We thought him one of the best witnesses we ever put on the stand in the line of his profession."

Another has said:

"From Maine to California, during the half century and over that he was prominently in active practice, Mr. Shedd's services were in demand, and during all that time his standing remained high and his reputation unsullied.

"J. Herbert Shedd is dead, but the many public works that were designed by him and constructed according to his directions, will, as imperishable monuments, live after him for centuries to come."

Those who knew Mr. Shedd intimately take just pride in his excellent work and in the fact that it was accomplished with so noble a record from the beginning to the end.

Mr. Shedd was elected a Member of the American Society of Civil Engineers on September 15th, 1869.

JAMES BLAINE MILLER, Assoc. M. Am. Soc. C. E.*

Died May 7th, 1915.

James Blaine Miller, the son of Thomas C. Miller, was born at Erie, Pa., on October 30th, 1883. He was graduated from the High School at that place in 1899, and from Oberlin College in 1903, with the degree of Bachelor of Arts.

During his last year at college, Mr. Miller passed the Civil Service examinations of the United States Coast and Geodetic Survey, and immediately on his graduation in June, 1903, entered that service as Aid.

From July, 1903, to September, 1906, as Member and Chief of Party, Mr. Miller was engaged on geodetic work in Alaska, Porto Rico, and in various parts of the United States. On his promotion to Assistant, in September, 1906, he was made Chief of Party, in command of the Coast and Geodetic Survey Steamer *Endeavor*, and spent several seasons in charting the unsurveyed waters of the Alaskan Coast and the Hawaiian Islands.

In 1908, Captain Miller was transferred to the Philippine Islands, and, in 1912, during a leave of absence, he spent some time in geodetic work for the Federal Government of Australia. His last cruise was

* Memoir prepared by Walter J. Ryan, Assoc. M. Am. Soc. C. E.

of two years duration and it was near the end of this cruise that he assisted in the rescue of the crew of the Revenue Cutter, *Tahoma*, which was wrecked on September 20th, 1914, among the Aleutian Islands. In a memorial presented to him by the men of the Revenue Cutter Service on that occasion the following is engraved:

"Captain Miller was the first to answer the distress call of the *Tahoma* and navigated his vessel with all possible speed to the scene of the wreck. He conducted a most thorough search for the small boats of the *Tahoma*, traversing dangerous and uncharted water both day and night until the last man was rescued."

In April, 1915, Captain Miller received leave of absence and sailed for Europe on the *Lusitania*. On July 20th, 1915, his body was recovered on the west coast of Ireland and after identification, was removed to Erie, Pa., where funeral services were held in December, 1915.

Captain Miller was elected an Associate Member of the American Society of Civil Engineers on April 2d, 1913.

LUDLOW VICTOR CLARK, Assoc. Am. Soc. C. E.*

Died December 28th, 1915.

Ludlow Victor Clark was born in Chatham, N. Y., on June 6th, 1863. He had been connected with the cement business in Philadelphia, Pa., for nearly thirty years, and, at the time of his death, was Second Vice-President of the Lawrence Portland Cement Company.

He was a man of unusual attainments and of a most attractive personality. He was an extensive traveler and a student of economic and industrial conditions, and the nature of his business made him keenly appreciative of all problems relating to the science of constructive engineering.

Mr. Clark was of that splendid type of character that compels respect and confidence, possessing a fine judgment for delicate action when business problems necessitated the arts of diplomacy and adjustment. He was very precise as to detail, but broad in dealing with subjects as a whole. His great ability was clearly recognized, and, in his death, the cement industry has suffered the loss of a good man. Loyalty and friendship were always the unwavering standards of his conduct, and his associates and friends will feel his loss deeply.

Mr. Clark is survived by a widow and one daughter. He was a member of the Union League Club of Philadelphia, a Mason of high degree, and a Noble of the Mystic Shrine.

Mr. Clark was elected an Associate of the American Society of Civil Engineers on October 4th, 1892.

* Memoir prepared by the Lawrence Portland Cement Company, Philadelphia, Pa.

PAPERS IN THIS NUMBER

"THE FLOW OF WATER IN IRRIGATION CHANNELS." GEORGE HENRY ELLIS. (To be presented Mar. 15th, 1916.)

"METHOD OF DESIGNING A RECTANGULAR REINFORCED CONCRETE FLAT SLAB, EACH SIDE OF WHICH RESTS ON EITHER RIGID OR YIELDING SUPPORTS." A. C. JANNI. (To be presented April 5th, 1916.)

"TEMPERATURE STRESSES IN A SERIES OF SPANS." TRESHAM D. GREGG.

PAPERS AND DISCUSSIONS CURRENT IN PROCEEDINGS

PAPERS IN THIS NUMBER

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PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

VOL. XLII—No. 3

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March, 1916

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PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

(INSTITUTED 1852)

VOL. XLII—No. 3

MARCH, 1916

Edited by the Secretary, under the direction of the Committee on Publications.

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American Society of Civil Engineers

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ON VALUATION OF PUBLIC UTILITIES: Frederic P. Stearns, Charles S. Churchill, Leonard Metcalf, William G. Raymond, Henry E. Riggs, Jonathan P. Snow, William J. Wilgus.

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The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

TELEPHONE NUMBER........................1446 Circle.
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AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PROCEEDINGS

This Society is not responsible for any statement made or opinion expressed in its publications.

SOCIETY AFFAIRS

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MINUTES OF MEETINGS

OF THE SOCIETY

February 16th, 1916.—The meeting was called to order at 8.30 P. M.; President Elmer L. Corthell in the chair; T. J. McMinn, Assistant Secretary, acting as Secretary; and present, also, 271 members and 33 guests.

A paper by A. B. Lueder, M. Am. Soc. C. E., and W. J. R. Wilson, Esq., entitled "Secure Subway Supports" was presented by Mr. Lueder and illustrated with lantern slides. The Assistant Secretary read a communication on the subject from H. G. Moulton, Esq., and the paper was discussed by Messrs. Richard A. Fiesel, J. H. O'Brien, Lazarus White, B. C. Collier, and A. B. Lueder.

The proposed movement of Society Headquarters was discussed by Messrs. Clemens Herschel, Alexander C. Humphreys, H. G. Stott, and the President.

The Assistant Secretary announced the following deaths:

Robert James Beach, of New York City, elected Member, May 2d, 1900; died February 7th, 1916.

Walter Frank Carr, of Seattle, Wash., elected Member, June 6th, 1894; died February 2d, 1916.

John Howard Johnston, of Nice, Alpes Maritimes, France, elected Member, March 1st, 1876; died in May, 1913.

William Jasper Nicolls, of Philadelphia, Pa., elected Member, June 5th, 1878; died February 14th, 1916.

George Way Swinburne, of East Orange, N. J., elected Member, May 7th, 1902; died February 3d, 1916.

Stevenson Towle, of New York City, elected Member, February 19th, 1868; died February 14th, 1916.

Charles Perkins Webber, of Panuco, Ver., Mexico, elected Associate Member, October 7th, 1908; Member, January 7th, 1913; died January 30th, 1916.

Adjourned.

March 1st, 1916.—The meeting was called to order at 8.30 P. M.; J. O. Eckersley, M. Am. Soc. C. E., in the chair; T. J. McMinn, Assistant Secretary, acting as Secretary; and present, also, 116 members and 12 guests.

The minutes of the Annual Meeting, January 19th, and of the meeting of February 2d, 1916, were approved as printed in *Proceedings* for February, 1916.

A paper by Joseph W. Ellms, M. Am. Soc. C. E., and John S. Gettrust, Esq., entitled "A Study of the Behavior of Rapid Sand Filters Subjected to the High-Velocity Method of Washing", was presented by the Assistant Secretary, and discussed by Messrs. F. A. Barbour, Robert Spurr Weston, H. Malcolm Pirnie, and John H. Gregory, Messrs. Barbour and Weston illustrating their remarks with lantern slides. Written discussions on this paper by Messrs. F. H. Stephenson, George E. Willcomb, and George W. Fuller were presented by title.

A paper by Henry S. Prichard, M. Am. Soc. C. E., entitled "The Effects of Straining Structural Steel and Wrought Iron", was presented by the author, and discussed by Ernst F. Jonson, Assoc. M. Am. Soc. C. E. Written discussions on this paper by Messrs. J. A. L. Waddell, C. A. P. Turner, H. F. Moore, Henry B. Seaman, J. A. McCulloch, F. N. Speller, James E. Howard, and T. D. Lynch were presented by title.

The Assistant Secretary announced the following deaths:

Thomas Francis McCrickett, of Detroit, Mich., elected Member, January 2d, 1907; died January 26th, 1916.

George Washington Vaughn, of Leavenworth, Kans., elected Member, June 3d, 1891; died February 3d, 1916.

Curtiss Millard, of North Egremont, Mass., elected Junior, April 3d, 1889; died February 16th, 1916.

Adjourned.

ANNOUNCEMENTS

The House of the Society is open from 9 A. M. to 10 P. M., every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

FUTURE MEETINGS

April 5th, 1916.—8.30 P. M.—This will be a regular business meeting. A paper by A. C. Janni, M. Am. Soc. C. E., entitled "Method of Designing a Rectangular Reinforced Concrete Flat Slab, Each Side of Which Rests on Either Rigid or Yielding Supports", will be presented for discussion.

This paper was printed in *Proceedings* for February, 1916.

April 19th, 1916.—8.30 P. M.— At this meeting a paper by James B. Hays, Jun. Am. Soc. C. E., entitled "Designing an Earth Dam Having a Gravel Foundation, with the Results Obtained in Tests on a Model", will be presented for discussion.

This paper is printed in this number of *Proceedings*.

ANNUAL CONVENTION

The Forty-eighth Annual Convention of the Society will be held at Pittsburgh, Pa., from June 27th to 30th, 1916, inclusive.

Arrangements for the Convention are in the hands of the following Local Committee:

George S. Davison, *Chairman*,

J. A. Atwood,	D. W. McNaugher,
R. A. Cummings,	Emil Swensson,
Richard Khuen,	E. B. Taylor,
Morris Knowles,	W. G. Wilkins,

Paul L. Wolfel.

SEARCHES IN THE LIBRARY

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

It sometimes happens that references are found which are not readily accessible to the person for whom the search is made. In that case the material may be reproduced by photography, and this can be done for members at the cost of the work to the Society, which is small. This method is particularly useful when there are drawings or figures in the text, which would be very expensive to reproduce by hand.

PAPERS AND DISCUSSIONS

Members and others who take part in the oral discussions of the papers presented are urged to revise their remarks promptly. Written communications from those who cannot attend the meetings should be sent in at the earliest possible date after the issue of a paper in *Proceedings.*

All papers accepted by the Publication Committee are classified by the Committee with respect to their availability for discussion at meetings.

Papers which, from their general nature, appear to be of a character suitable for oral discussion, will be published as heretofore in *Proceedings,* and set down for presentation to a future meeting of the Society, and on these, oral discussions, as well as written communications, will be solicited.

All papers which do not come under this heading, that is to say, those which, from their mathematical or technical nature, in the opinion of the Committee, are not adapted to oral discussion, will not be scheduled for presentation to any meeting. Such papers will be published in *Proceedings* in the same manner as those which are to be presented at meetings, but written discussions only will be requested for subsequent publication in *Proceedings* and with the paper in the volumes of *Transactions.*

The Board of Direction has adopted rules for the preparation and presentation of papers, which will be found on page 429 of the August, 1913, *Proceedings.*

LOCAL ASSOCIATIONS OF MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

San Francisco Association

The San Francisco Association of Members of the American Society of Civil Engineers holds regular bi-monthly meetings, with banquet, and weekly informal luncheons. The former are held at 6 P. M., at the Palace Hotel, on the third Tuesday of February, April, June, August, and October, and the third Friday of December, the last being the Annual Meeting of the Association.

Informal luncheons are held at 12.15 P. M., every Wednesday, and the place of meeting may be ascertained by communicating with the Secretary of the Association, E. T. Thurston, 713 Mechanics' Institute, 57 Post Street.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in San Francisco, and any such member will be gladly welcomed as a guest.

Colorado Association

The meetings of the Colorado Association of Members of the American Society of Civil Engineers (Denver, Colo.) are held on the second Saturday of each month, except July and August. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary, L. R. Hinman, 1400 West Colfax Ave., Denver, Colo. The meetings are usually preceded by an informal dinner. Members of the American Society of Civil Engineers will be welcomed at these meetings.

Weekly luncheons are held on Wednesdays, at 12.30 P. M., at Clarke's Restaurant, 1632 Champa Street.

Visiting members are urged to attend the meetings and luncheons.

(Abstract of Minutes of Meeting)

January 15th, 1916.—The meeting was called to order at the Denver Athletic Club; President John E. Field in the chair; L. R. Hinman, Secretary; and present, also, 21 members and 7 guests.

The minutes of the meeting of November 13th, 1915, were read and approved.

The resignations of Messrs. A. G. Allan and H. V. Knouse, as members of the Association, were accepted.

The matter of the Luncheon Postal Notice was discussed, and on motion, duly seconded, a vote was taken, resulting in a decision to discontinue such notice.

Mr. L. B. Curtis addressed the meeting on the subject of the "Hydro-Electric Development of the Nevada-California Power Corporation", illustrating his remarks with lantern slides, and the subject was informally discussed by those present.

On motion, duly seconded, a vote of thanks was extended to Mr. Curtis for his address.

Adjourned.

Atlanta Association

The Atlanta Association of Members of the American Society of Civil Engineers was organized on March 14th, 1912. The Association holds its meetings at the University Club, Atlanta, Ga.

At the meeting of the Association on January 9th, 1915, the following officers were elected for the ensuing year: President, Park A. Dallis; First Vice-President, B. M. Hall; Second Vice-President, P. H. Norcross; Secretary-Treasurer, T. B. Branch.

Baltimore Association

The Baltimore Association of Members of the American Society of Civil Engineers was organized on May 6th, 1914, and the proposed Constitution was approved by the Board of Direction at its meeting of September 2d, 1914.

At the meeting of the Association on May 5th, 1915, the following officers were elected: President, Thomas D. Pitts; Secretary-Treasurer, Charles J. Tilden; Directors, J. E. Greiner, C. W. Hendrick, B. P. Harrison, B. T. Fendall, Mason D. Pratt, R. Keith Compton, R. B. Morse, and H. G. Shirley.

Cleveland Association

The proposed Constitution of the Cleveland Association of Members of the American Society of Civil Engineers was considered and approved by the Board of Direction of the Society on January 6th, 1915.

At the meeting of the Association on December 18th, 1915, the following officers were elected for the ensuing year: President, Robert Hoffmann; Vice-President, Wilbur J. Watson; and Secretary-Treasurer, George H. Tinker.

Louisiana Association

At the meeting of the Louisiana Association of Members of the American Society of Civil Engineers (New Orleans, La.), on April 14th, 1915, the following officers were elected for the ensuing year: J. F. Coleman, President; W. B. Gregory and A. M. Shaw, Vice-Presidents; Ole K. Olsen, Treasurer; and E. H. Coleman, Secretary.

Northwestern Association

The proposed Constitution of the Northwestern Association of Members of the American Society of Civil Engineers (St. Paul and Minneapolis, Minn.) was considered and approved by the Board of Direction of the Society on November 4th, 1914.

The officers of the Association are as follows: President, W. L. Darling; First Vice-President, George L. Wilson; Second Vice-President, L. W. Rundlett; Secretary, R. D. Thomas; and Treasurer, A. F. Meyer.

Philadelphia Association

The meetings of the Philadelphia Association of Members of the American Society of Civil Engineers are held at the Engineers' Club of Philadelphia, 1317 Spruce Street.

The officers of the Association are as follows: President, Edward B. Temple; Vice-Presidents, Edgar Marburg and John Sterling Deans; Directors, J. W. Ledoux, H. S. Smith, Henry H. Quimby, and George A. Zinn; Past-Presidents, George S. Webster and Richard L. Humphrey; Treasurer, S. M. Swaab; and Secretary, W. L. Stevenson.

Portland, Ore., Association

At the Annual Meeting of the Association on September 28th, 1915, the following officers were elected for the ensuing year: President, J. P. Newell; First Vice-President, John T. Whistler; Second Vice-

President, E. B. Thomson; Treasurer, Russell Chase; and Secretary, J. A. Currey.

St. Louis Association

The proposed Constitution of the St. Louis Association of Members of the American Society of Civil Engineers was considered and approved by the Board of Direction of the Society on October 7th, 1914.

The following officers have been elected: President, J. A. Ockerson; First Vice-President, Edward E. Wall; Second Vice-President, F. J. Jonah; Secretary-Treasurer, Gurdon G. Black. The meetings of the Association are held at the Engineers' Club Auditorium.

San Diego Association

The San Diego Association of Members of the American Society of Civil Engineers was organized on February 5th, 1915, and officers have been elected, as follows: President, George Butler; Vice-President, Willis J. Dean; and Secretary-Treasurer, J. R. Comly.

At its meeting of September 20th, 1915, the Board of Direction considered and approved the proposed Constitution of the San Diego Association of Members of the American Society of Civil Engineers.

Seattle Association

The Seattle Association of Members of the American Society of Civil Engineers was organized on June 30th, 1913.

The officers of the Association for 1916 are as follows: President, A. O. Powell; Vice-President, Joseph Jacobs; and Secretary-Treasurer, Carl H. Reeves.

(Abstract of Minutes of Meeting)

January 31st, 1916.—The Annual Meeting was called to order at 7.00 P. M., at the College Club; President R. H. Ober in the chair; Carl H. Reeves, Secretary; and present, also, 52 members and guests.

The Report of the Secretary-Treasurer for 1915, showing an increase of 14 in membership and a cash balance of $79.32, was read and approved.

President Ober, in a brief address, reviewed the work of the Association during 1915, and then introduced the guest of honor, Charles H. Rust, M. Am. Soc. C. E., who presented a paper on "The New Water Supply of Victoria", illustrating his remarks with stereopticon views.

The minutes of the meeting of December 27th, 1915, were read and approved.

Communications from the Pacific Northwest Society of Engineers, in re its meeting of February 5th, 1916; from Mr. F. W. D. Holbrook, in re his election as an Honorary Member of the Association; and from the Secretary of the Portland, Ore., Association, in re competition for plans for the Inter-County Bridge at Salem, Ore., were presented.

On motion, duly seconded, the President-elect was ordered to appoint a committee, consisting of himself and four other members of the Association, to care for and entertain members of the Society while sojourning in Seattle during the coming year.

Mr. F. T. Crowe addressed the meeting briefly.

The officers of the Association for 1916 were elected, as follows: President, A. O. Powell; Vice-President, Joseph Jacobs; and Secretary-Treasurer, Carl H. Reeves.

On motion, duly seconded, the auditing of the books of the Secretary-Treasurer was waived.

Messrs. R. H. Thomson and S. H. Hedges were appointed a Committee to escort Mr. Powell, the President-elect, to the chair, after which brief addresses were made by Messrs. S. H. Hedges, W. E. Herring, G. R. Hawes, L. M. Grant, L. V. Branch, Joseph Jacobs, and R. H. Thomson.

Adjourned.

Southern California Association

The Southern California Association of Members of the American Society of Civil Engineers (Los Angeles, Cal.) holds regular bi-monthly meetings, with banquet, on the second Wednesday of February, April, June, August, October, and December, the last being the Annual Meeting of the Association.

Informal luncheons are held at 12.15 P. M. every Wednesday, and the place of meeting may be ascertained from the Secretary of the Association, W. K. Barnard, 701 Central Building, Los Angeles, Cal.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in Los Angeles, and any such member will be gladly welcomed as a guest at any of the meetings or luncheons.

The officers of the Association for 1916, are as follows: President, William Mulholland; First Vice-President, H. Hawgood; Second Vice-President, L. C. Hill; Secretary, W. K. Barnard; and Treasurer, C. H. Lee.

Spokane Association

The proposed Constitution of the Spokane Association of Members of the American Society of Civil Engineers was considered and approved by the Board of Direction of the Society on March 4th, 1914. Ulysses B. Hough is President.

Texas Association

The proposed Constitution of the Texas Association of Members of the American Society of Civil Engineers was considered and approved by the Board of Direction of the Society on December 31st, 1913. The headquarters of the Association is Dallas, Tex. John B. Hawley is President.

MINUTES OF MEETINGS OF SPECIAL COMMITTEES TO REPORT UPON ENGINEERING SUBJECTS

Special Committee on Steel Columns and Struts

January 20th, 1916.—The meeting was called to order at 10 A. M. at the House of the Society. Present, George H. Pegram (Chairman), James H. Edwards, Charles F. Loweth, Rudolph P. Miller, Ralph Modjeski, George F. Swain, and Lewis D. Rights (Secretary). There were also present Dr. Olshausen, representing the U. S. Government Bureau of Standards, and W. H. Moore, M. Am. Soc. C. E., representing the Steel Column Sub-Committee of the American Railway Engineering Association. C. G. E. Larsson, M. Am. Soc. C. E., of the American Bridge Company, was also present.

The minutes of the meeting of November 19th, 1915, were approved.

Mr. Edwards reported that all the material for the supplementary test programme had been shipped from the shop of the American Bridge Company, and Dr. Olshausen stated that a portion had been received at Washington and delivered to the Bureau of Standards.

Mr. Swain was continued as a committee of one to confer further with Col. Wheeler, of Watertown Arsenal, in reference to the column tests which are being conducted there.

Mr. Worcester (who was not present) was appointed a committee of one to elaborate the discussion which he submitted under the heading "Factor of Safety", and the members of the Committee were requested to send in their discussions on the subject before February 15th, 1916.

Messrs. Edwards and Swain, and Dr. Olshausen were appointed a committee to arrange for making the tests on the columns in the supplementary programme. Considerable discussion was brought out as to how these tests should be carried out.

The Chairman and the Secretary were authorized to make a budget for the ensuing year and submit it to the Board of Direction for approval.

It was decided to hold the next meeting in Washington, D. C., at some date near April 1st, to be determined by the Chairman.

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms, and at all meetings:

American Institute of Electrical Engineers, 33 West Thirty-ninth Street, New York City.

American Institute of Mining Engineers, 29 West Thirty-ninth Street, New York City.

American Society of Mechanical Engineers, 29 West Thirty-ninth Street, New York City.

Architekten-Verein zu Berlin, Wilhelmstrasse 92, Berlin W. 66, Germany.

Associação dos Engenheiros Civis Portuguezes, Lisbon, Portugal.

Australasian Institute of Mining Engineers, Melbourne, Victoria, Australia.

Boston Society of Civil Engineers, 715 Tremont Temple, Boston, Mass.

Brooklyn Engineers' Club, 117 Remsen Street, Brooklyn, N. Y.

Canadian Society of Civil Engineers, 176 Mansfield Street, Montreal, Que., Canada.

Civil Engineers' Society of St. Paul, St. Paul, Minn.

Cleveland Engineering Society, Chamber of Commerce Building, Cleveland, Ohio.

Cleveland Institute of Engineers, Middlesbrough, England.

Dansk Ingeniorforening, Amaliegade 38, Copenhagen, Denmark.

Detroit Engineering Society, 46 Grand River Avenue, West, Detroit, Mich.

Engineers and Architects Club of Louisville, 1412 Starks Building, Louisville, Ky.

Engineers' Club of Baltimore, 6 West Eager Street, Baltimore, Md.

Engineers' Club of Kansas City, E. B. Murray, Secretary, 920 Walnut Street, Kansas City, Mo.

Engineers' Club of Minneapolis, 17 South Sixth Street, Minneapolis, Minn.

Engineers' Club of Philadelphia, 1317 Spruce Street, Philadelphia, Pa.

Engineers' Club of St. Louis, 3817 Olive Street, St. Louis, Mo.

Engineers' Club of Toronto, 96 King Street, West, Toronto, Ont., Canada.

Engineers' Club of Trenton, Trent Theatre Building, 12 North Warren Street, Trenton, N. J.

Engineers' Society of Northeastern Pennsylvania, 415 Washington Avenue, Scranton, Pa.

Engineers' Society of Pennsylvania, 31 South Front Street, Harrisburg, Pa.

Engineers' Society of Western Pennsylvania, 2511 Oliver Building, Pittsburgh, Pa.

Institute of Marine Engineers, The Minories, Tower Hill, London, E., England.

Institution of Engineers of the River Plate, Calle 25 de Mayo 195, Buenos Aires, Argentine Republic.

Institution of Naval Architects, 5 Adelphi Terrace, London, W. C., England.

Junior Institution of Engineers, 39 Victoria Street, Westminster, S. W., London, England.

Koninklijk Instituut van Ingenieurs, The Hague, The Netherlands.

Louisiana Engineering Society, State Museum Building, Chartres and St. Ann Streets, New Orleans, La.

Memphis Engineers' Club, Memphis, Tenn.

Midland Institute of Mining, Civil and Mechanical Engineers, Sheffield, England.

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UEBER GESCHICHTE UND BAU DES PANAMA-KANALES.

Von K. E. Hilgard, M. Am. Soc. C. E. Paper, 9¾ x 6½ in., illus., 113 pp. Zürich, Art. Institut Orell Füssli. 6 Marks.

The subject-matter of this book is said to have been first used by the author as a lecture before various scientific and technical societies in different cities and towns in Switzerland, and is, therefore, necessarily limited in scope. After a short history of the Panama Canal, the author describes the most essential parts of its construction and operation, including the sanitation of the Canal Zone, the various kinds of machinery used and its application to the work, the labor organization and housing problems, the dams, locks, and slides, etc. He includes the total costs of construction and a comparison of the trade and political importance of the Canal to North America and the rest of the world. The text is fully illustrated by maps, graphical tables, and official photographs, and the author has also given a short bibliography of recent literature pertaining to the subject. The Chapter headings are: Kurzer Ueberblick der Geschichte des Kanales; Allgemeine Beschreibung des Kanales, das allgemeine Technische sowie Sonderprobleme des Kanalbaues and die Kanalzone, Organisation der Kanalcommission; Hygiene und Sanierung der Kanalzone; Die einzelnen Bauten; Die wichtigsten Arbeitsmaschinen und wesentlichsten Arbeitsleistungen; Die Arbeiter-und Lebensverhältnisse; Die Vollendung des Kanales und die Sicherung seines Betriebes, seitherige Rutschungen im Culebra-Einschnitt; Die Erbauer des Kanales; Bedenken und Einwendungen gegen die erfolgreiche Vollendung und Benutzung des Kanales; Vergleich des Panama-Kanales mit einigen anderen Meereskanälen; Die Bedeutung des Panama-Kanales für Nord-Amerika und den Weltverkehr; Baukosten und Schluss; Einige Angaben über neuere einschlägige Literatur; Verzeichnis der graphischen Beilagen und Abbildungen.

DAMS AND WEIRS:

An Analytical and Practical Treatise on Gravity Dams and Weirs; Arch and Buttress Dams; Submerged Weirs; and Barrages. By W. G. Bligh, M. Am. Soc. C. E. Cloth, 8½ x 5¾ in., illus., 206 pp. Chicago, American Technical Society, 1915. (Donated by the Author.)

The great progress made in recent years in dam and weir construction, by reason of the vast irrigation and power projects which have been undertaken by the various Governments and hydro-electric companies, and the use of reinforced concrete as a standard material for building such dams, has served, it is stated, to multiply the types of design and increased the need of a brief but authoritative work on the subject. The author, it is said, has designed and built weirs and dams in India, Egypt, Canada, and the United States, and is, therefore, qualified to discuss the subject, not only from its historic side, but from the modern practical side as well. In addition to a careful analysis of each modern type of profile, he has given, it is stated, critical studies of examples of each type, showing the good and bad points of the design. He has also included a number of practical problems and their solution, using both the graphical and analytical methods, the former method being explained in detail as occasion demands. Numerous drawings and photographs have also been used to illustrate the text. The Chapter headings are: Gravity Dams; Design of Dams; Unusually High Dams; Notable Existing Dams; Special Foundations; Gravity Overfall Dams or Weirs; Arched Dams; Multiple Arch or Hollow Arch Buttress Dams; Hollow Slab Buttress Dams; Submerged Weirs Founded on Sand; Open Dams or Barrages; Index.

IRRIGATION PRACTICE AND ENGINEERING:

Volume III, Irrigation Structures and Distribution System. By B. A. Etcheverry, Assoc. M. Am. Soc. C. E. Cloth, 9¼ x 6¼ in., illus., 15 + 438 pp. New York and London, McGraw-Hill Book Company, Inc., 1916. $4.00.

In Volumes I and II of this work, the author has discussed the Use of Irrigation Water and the Conveyance of Water, respectively, and, in this (the third and last) volume, he describes, in Chapters I to VII, the various structures, and, in Chapters VIII to XIII, the distribution system, used in irrigation practice. The preface states that Volumes II and III are essentially devoted to a presentation of the fundamental

* Unless otherwise specified, books in this list have been donated by the publishers.

principles and problems of irrigation engineering, and, although intended as text-books for use in technical schools, sufficient descriptive matter and cost data have been added to make them valuable as reference books for engineers engaged in the construction and operation of irrigation systems. As presented in these two volumes, the subject-matter, it is said, is confined largely to canals and other works pertaining to the usual types of irrigation systems. No attempt has been made, it is stated, to discuss the subject of dams for the storage of water or high masonry dams for diversion purposes, but detailed descriptions of low dams for diversion weirs are included. The book is illustrated with many drawings and photographs of constructed works, and at the end of each chapter tabulated references are given to other works pertaining to the subject discussed in that chapter. The Contents are: Diversion Works; Scouring Sluices, Fish Ladders, Logways; Main Headgates or Regulator for Canal System; Canal Spillways, Escapes and Wasteways; Sand Gates, Sand Boxes; Crossings with Drainage Channels; Drops and Chutes in Canals; Distribution System; Check Gates; Lateral Headgates and Delivery Gates; Road and Railroad Crossings with Canals, Culverts, Inverted Siphons and Bridges; Special Types of Distribution Systems: Wooden Flume, Wooden Pipe, and Cement Pipe Distribution Systems; Measuring Devices; Index.

MUNICIPAL FREEDOM:

A Study of the Commission Government. By Oswald Ryan. With an Introduction by A. Lawrence Lowell. (The American Books.) Cloth, $7\frac{1}{4}$ x 5 in., 16 + 233 pp. New York, Doubleday, Page & Company, 1915. 60 cents.

The Commission Government, the author states, has had a larger share of consideration at the hands of charter reformers and students of government than any other single measure of municipal reform, and his aim in this book, it is said, is to discuss the possibilities and efficiencies of the plan in relation to its future adoption as the prevailing municipal system in the United States, rather than to relate the story of various commission governments. The subject-matter, it is stated, is based largely on the author's personal investigations in various cities of the United States since 1910, and in the Appendix he has included the Des Moines Plan of commission government, as provided by the Iowa Commission Government Act, the Commission-Manager Plan, as outlined in the Dayton, Ohio, Charter, and the Preferential Ballot, as provided in the charter of Grand Junction, Colo. He has also included a bibliography of selected references on the subject of Commission Government. The Contents are: The New Departure in Municipal Democracy; A Tale of Two Cities; Democracy and Efficiency; Fixing Responsibility; Changing Municipal Organization to Preserve Municipal Democracy; The Coming of the Burgomaster; Is the Party System Passing from the City?; Vitalizing the Ballot; Municipal Freedom; Appendix: The Des Moines Plan; The Commission-Manager Plan; Preferential Voting; Selected References on Commission Government.

INDUSTRIAL LEADERSHIP.

By H. L. Gantt. Cloth, $7\frac{3}{4}$ x $5\frac{1}{4}$ in., illus., 12 + 128 pp. New Haven, Yale University Press; London, Humphrey Milford; Cambridge University Press, 1916. $1.00.

In a secondary title, it is stated that the subject-matter of this book is made up of the addresses delivered in the Page Lecture Series, 1915, before the Senior Class of the Sheffield Scientific School of Yale University. In these lectures the author, it is said, has attempted to indicate the organization and executive methods on which to establish an industrial democracy which will be more effective than any such system developed under autocracy. He emphasizes the importance of industrial leadership and the responsibility of engineering schools for training such leaders, the methods to be followed for the development and training of workmen, and the results obtained by such methods. One of the most important phases of the question discussed herein is said to be how far the State should go with industrial and vocational training. It is exceedingly important, it is stated, that the industries themselves give as much of such training as possible before the State takes up the work, and in his discussion, the author, it is said, shows how much they can accomplish by the methods outlined in these lectures and the good results to be obtained. The Contents are: Industrial Leadership; Training Workmen; Principles of Task Work; Results of Task Work; Production and Sales.

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Depreciation and Wasting Assets and Their Treatment in Assessing Annual Profit and Loss. By P. D. Leake. London, 1912.

Valuation of Real Property: A Guide to the Principles of Valuation of Lands and Buildings, etc., for Various Purposes, Including the Taxation of Land Values, with Numerous Examples. By Clarence A. Webb. Third Edition, Revised and Enlarged. By Arthur Hemmings. London, 1913.

Formeln und Tabellen für den Eisenbau, nebst den wichtigsten Hochbauvorschriften und Brückenverordnungen Preussens und Oesterreichs. Von Friedrich Bleich. Wien, 1915.

Beton-Kalender, 1916: Taschenbuch für Beton- u. Eisenbetonbau, sowie die verwandten Fächer. Unter Mitwirkung hervorragender Fachmänner, herausgegeben von der Zeitschrift *Beton u. Eisen.* XI. Jahrgang. 2. Vol. Berlin, 1915.

The Utilities Magazine; Vol. 1, No. 3, January, 1916: Proceedings of the Conference on Valuation. Philadelphia.

Illustrierte technische Wörterbücher: Unter Mitwirkung hervorragender Fachleute des In- und Auslandes. Herausgegeben von Alfred Schlomann. Band 12: Wassertechnik, Lufttechnik, Kältetechnik. München und Berlin, 1915.

Properties of Steam and Ammonia. By G. A. Goodenough. New York and London, 1915.

Petroleum Technologist's Pocket Book. By *Sir* Boverton Redwood and Arthur W. Eastlake. London, 1915.

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RESIGNATIONS

MEMBERS	Date of Resignation.
HAYNES, GEORGE ALBERT	Dec. 31, 1915

DEATHS

BEACH, ROBERT JAMES. Elected Member, May 2d, 1900; died February 7th, 1916.

CARR, WALTER FRANK. Elected Member, June 6th, 1894; died February 2d, 1916.

JOHNSTON, JOHN HOWARD. Elected Member, March 1st, 1876; died in May, 1913.

MCCRICKETT, THOMAS FRANCIS. Elected Member, January 2d, 1907; died January 26th, 1916.

MILLARD, CURTISS. Elected Junior, April 3d, 1889; died February 16th, 1916.

NICOLLS, WILLIAM JASPER. Elected Member, June 5th, 1878; died February 14th, 1916.

SWINBURNE, GEORGE WAY. Elected Member, May 7th, 1902; died February 3d, 1916.

TOWLE, STEVENSON. Elected Member, February 19th, 1868; died February 14th, 1916.

WEBBER, CHARLES PERKINS. Elected Associate Member, October 7th, 1908; Member, January 7th, 1913; died January 30th, 1916.

Total Membership of the Society, March 2d, 1916, 7 904.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST

(February 2d, to February 26th, 1916)

NOTE.—*This list is published for the purpose of placing before the members of this Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS

In the subjoined list of articles, references are given by the number prefixed to each journal in this list:

(2) *Proceedings,* Engrs. Club of Phila., Philadelphia, Pa.
(3) *Journal,* Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal,* Western Soc. of Engrs., Chicago, Ill., 50c.
(5) *Transactions,* Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly,* Columbia Univ., New York City, 50c.
(7) *Gesundheits Ingenieur,* München, Germany.
(8) *Stevens Institute Indicator,* Hoboken, N. J., 50c.
(9) *Engineering Magazine,* New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, 432 Fourth Ave., New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News,* New York City, 15c.
(14) *Engineering Record,* New York City, 10c.
(15) *Railway Age Gazette,* New York City, 15c.
(16) *Engineering and Mining Journal,* New York City, 15c.
(17) *Electric Railway Journal,* New York City, 10c.
(18) *Railway Review,* Chicago, Ill., 15c.
(19) *Scientific American Supplement,* New York City, 10c.
(20) *Iron Age,* New York City, 20c.
(21) *Railway Engineer,* London, England, 1s. 2d.
(22) *Iron and Coal Trades Review,* London, England, 6d.
(23) *Railway Gazette,* London, England, 6d.
(24) *American Gas Light Journal,* New York City, 10c.
(25) *Railway Mechanical Engineer,* New York City, 20c.
(26) *Electrical Review,* London, England, 4d.
(27) *Electrical World,* New York City, 10c.
(28) *Journal,* New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal,* Royal Society of Arts, London, England, 6d.
(30) *Annales des Travaux Publics de Belgique,* Brussels, Belgium, 4 fr.
(31) *Annales* de l'Assoc. des Ing. Sortis des Ecoles Spéciales de Gand, Brussels, Belgium, 4 fr.
(32) *Mémoires et Compte Rendu des Travaux,* Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil,* Paris, France, 1 fr.
(34) *Portefeuille Economiques des Machines,* Paris, France.
(35) *Nouvelles Annales de la Construction,* Paris, France.
(36) *Cornell Civil Engineer,* Ithaca, N. Y.
(37) *Revue de Mécanique,* Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways,* Paris, France.
(39) *Technisches Gemeindeblatt,* Berlin, Germany, 0, 70m.
(40) *Zentralblatt der Bauverwaltung,* Berlin, Germany, 60 pfg.
(41) *Electrotechnische Zeitschrift,* Berlin, Germany.
(42) *Proceedings,* Am. Inst. Elec. Engrs., New York City, $1.
(43) *Annales des Ponts et Chaussées,* Paris, France.
(44) *Journal,* Military Service Institution, Governors Island, New York Harbor, 50c.
(45) *Coal Age,* New York City, 10c.
(46) *Scientific American,* New York City, 15c.
(47) *Mechanical Engineer,* Manchester, England, 3d.
(48) *Zeitschrift,* Verein Deutscher Ingenieure, Berlin, Germany, 1, 60m.
(49) *Zeitschrift für Bauwesen,* Berlin, Germany.
(50) *Stahl und Eisen,* Düsseldorf, Germany.
(51) *Deutsche Bauzeitung,* Berlin, Germany.
(52) *Rigasche Industrie-Zeitung,* Riga, Russia, 25 kop.
(53) *Zeitschrift,* Oesterreichischer Ingenieur und Architekten Verein, Vienna, Austria, 70h.
(54) *Transactions,* Am. Soc. C. E., New York City, $12.
(55) *Transactions,* Am. Soc. M. E., New York City, $10.
(56) *Transactions,* Am. Inst. Min. Engrs., New York City, $6.

(57) *Colliery Guardian,* London, England, 5d.
(58) *Proceedings,* Engrs.' Soc. W. Pa., 2511 Oliver Bldg., Pittsburgh, Pa., 50c.
(59) *Proceedings,* American Water-Work Assoc., Troy, N. Y.
(60) *Municipal Engineering,* Indianapolis, Ind., 25c.
(61) *Proceedings,* Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *Steel and Iron,* Thaw Bldg., Pittsburgh, Pa., 10c.
(63) *Minutes of Proceedings,* Inst. C. E., London, England.
(64) *Power,* New York City, 5c.
(65) *Official Proceedings,* New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting,* London, England, 6d.
(67) *Cement and Engineering News,* Chicago, Ill., 25c.
(68) *Mining Journal,* London, England, 6d.
(69) *Der Eisenbau,* Leipzig, Germany.
(71) *Journal,* Iron and Steel Inst., London, England.
(71a) *Carnegie Scholarship Memoirs,* Iron and Steel Inst., London, England.
(72) *American Machinist,* New York City, 15c.
(73) *Electrician,* London, England, 18c.
(74) *Transactions,* Inst. of Min. and Metal., London, England.
(75) *Proceedings,* Inst. of Mech. Engrs., London, England.
(76) *Brick,* Chicago, Ill., 20c.
(77) *Journal,* Inst. Elec. Engrs., London, England, 5s.
(78) *Beton und Eisen,* Vienna, Austria, 1, 50m.
(79) *Forscherarbeiten,* Vienna, Austria.
(80) *Tonindustrie Zeitung,* Berlin, Germany.
(81) *Zeitschrift für Architektur und Ingenieurwesen,* Wiesbaden, Germany.
(82) *Mining and Engineering World,* Chicago, Ill., 10c.
(83) *Gas Age,* New York City, 15c.
(84) *Le Ciment,* Paris, France.
(85) *Proceedings,* Am. Ry. Eng. Assoc., Chicago, Ill.
(86) *Engineering-Contracting,* Chicago, Ill., 10c.
(87) *Railway Engineering and Maintenance of Way,* Chicago, Ill., 10c.
(88) *Bulletin* of the International Ry. Congress Assoc., Brussels, Belgium.
(89) *Proceedings,* Am. Soc. for Testing Materials, Philadelphia, Pa., $5.
(90) *Transactions,* Inst. of Naval Archts., London, England.
(91) *Transactions,* Soc. Naval Archts. and Marine Engrs., New York City.
(92) *Bulletin,* Soc. d'Encouragement pour l'Industrie Nationale, Paris, France.
(93) *Revue de Métallurgie,* Paris, France, 4 fr. 50.
(95) *International Marine Engineering,* New York City, 20c.
(96) *Canadian Engineer,* Toronto, Ont., Canada, 10c.
(98) *Journal,* Engrs. Soc. Pa., Harrisburg, Pa., 30c.
(99) *Proceedings,* Am. Soc. of Municipal Improvements, New York City, $2.
(100) *Professional Memoirs,* Corps of Engrs., U. S. A., Washington, D. C., 50c.
(101) *Metal Worker,* New York City, 10c.
(102) *Organ für die Fortschritte des Eisenbahnwesens,* Wiesbaden, Germany.
(103) *Mining Press,* San Francisco, Cal., 10c.
(104) *The Surveyor and Municipal and County Engineer,* London, England, 6d.
(105) *Metallurgical and Chemical Engineering,* New York City, 25c.
(106) *Transactions,* Inst. of Min. Engrs., London, England, 6s.
(107) *Schweizerische Bauzeitung,* Zürich, Switzerland.
(108) *Iron Tradesman,* Atlanta, Ga., 10c.
(109) *Journal,* Boston Soc. C. E., Boston, Mass., 50c.
(110) *Journal,* Am. Concrete Inst., Philadelphia, Pa., 50c.
(111) *Journal of Electricity, Power and Gas,* San Francisco, Cal., 25c.
(112) *Internationale Zeitschrift für Wasser-Versorgung,* Leipzig, Germany.
(113) *Proceedings,* Am. Wood Preservers' Assoc., Baltimore, Md.
(114) *Journal,* Institution of Municipal and County Engineers, London, England, 1s. 6d.

LIST OF ARTICLES

Bridges.

On Impact Coefficients for Railway Girders.* Charles William Anderson. (63) Vol. 200, 1915.
Martins Creek Viaduct, Lackawanna & Western.* (87) Feb.
Some Minor Problems in a Highway Bridge Design.* L. M. Hastings. (109) Feb.
Concrete Railway Trestles.* (13) Feb. 3.
Two Early Suspension Bridges Just Taken Down.* (13) Feb. 3.
Load Tests of Foundation Soil in the Philippines. (13) Feb. 3.
Methods and Equipment Used in Constructing a Reinforced Concrete Viaduct at Danville, Ill.* N. B. Garver. (86) Feb. 9.
Three-Hinged Concrete Bridge Fails by Undermining.* (13) Feb. 10.
Bascule Bridge of Short Span.* (13) Feb. 10.
Two Large Concrete Viaducts on the St. Paul.* (15) Feb. 11.

* Illustrated.

Bridges—(Continued).

Highest Arch Highway Viaduct of Striking Appearance Economically Constructed.* (14) Feb. 12.
Painting and Maintaining Steel Highway Bridges. George Hogarth. (96) Feb. 17.
The Reconstruction of the Ohio Connecting Bridge.* (15) Feb. 18.
Raising a Three-Span Bridge Under Traffic.* (15) Feb. 18.
Woodside-Winfield Cut-Off of the Long Island R. R.* (18) Feb. 19.
Design and Construction of the Substructure for a Three-Track Trunnion Bascule Bridge in Chicago, Ill.* (86) Feb. 23.
Concrete Highway Trestle.* (13) Feb. 24.
City Bought Bridge Materials in Advance. (13) Feb. 24.
Patent for Arch Reinforcement Declared Valid.* (14) Feb. 26.
Reinforced-Concrete Slab Tests Show Time Effects. A. T. Goldbeck and E. B. Smith. (14) Feb. 26.
Le Nouveau Viaduc en Béton sur le Big Creek à Cleveland (Ohio, É-U.)* (33) Jan. 15.
Les Ponts de Montauban.* Charles Rabut. (33) Jan. 29.
Neues Verfahren zur raschen Ermittelung der Abmessungen und Eiseneinlagen von Gewölbefugen.* R. Färber. (51) Serial beginning Sup. No. 11, 1915.
Eine Eisenbetonbogenbrücke in Kristianstad (Schweden).* David Andersson. (78) Jan. 4.

Electrical.

The Electrolytic Action of Return Currents in Electric Tramways on Gas- and Water-Mains; and the Best Means of Providing against Electrical Disturbances.* Harry Edward Yerbury. (63) Vol. 200, 1915.
Central Station Steel Mill Electrification.* Brent Wiley and Wilfred Sykes. (Paper read before the Assoc. of Iron and Steel Elec. Engrs.) (62) Oct. 1, 1915.
Purchased Power for Steel Mill Operation. C. S. Lankton. (Paper read before the Assoc. of Iron and Steel Elec. Engrs.) (62) Oct. 1, 1915.
Late Development in Electrical Equipment.* K. A. Pauly. (Paper read before the Assoc. of Iron and Steel Elec. Engrs.) (62) Serial beginning Oct. 1, 1915.
Pressed Steel in Manufacture of Electric Motors.* C. W. Starker. (72) Jan. 13.
The Double Dynamometer Wattmeter.* C. V. Drysdale. (73) Serial beginning Jan. 14.
Modernization of Power Plant in Factories. W. A. Tookey. (Paper read before the Junior Institution of Engrs.) (47) Serial beginning Jan. 14.
Notes on the Ignition of Explosive Gas Mixtures by Electric Sparks.* J. D. Morgan. (77) Jan. 15.
Conway Building Power Plant.* Thomas Wilson. (64) Serial beginning Jan. 18.
Municipal Electricity Supply at Johannesburg. R. Turnbull Mawdesley. (26) Serial beginning Jan. 21.
A Comparison of 600, 1 200, and 2 400 Volt Switchboards.* (12) Jan. 21.
On Microphones and Microphonic Contacts.* P. O. Pedersen. (Abstract from *Elektroteknikeren.*) (73) Serial beginning Jan. 28.
The Goodman Storage Battery Locomotive, Particularly the Articulated Type.* E. C. De Wolf. (82) Jan. 29.
Standby Battery for A. C. Distribution Service.* J. Lester Woodbridge. (27) Jan. 29.
Electric Service in a Cotton-Duck Mill.* (27) Jan. 29.
The Voltmeter Coil in Testing Transformers. A. B. Hendricks, Jr. (42) Feb.
The Municipally-Operated Electrical Utilities of Western Canada.* A. G. Christie. (42) Feb.
A Method of Determining the Correctness of Polyphase Wattmeter Connections.* W. B. Kouwenhoven. (42) Feb.
The Crest Voltmeter.* L. W. Chubb. (42) Feb.
Crest Voltmeters.* C. H. Sharp and E. D. Doyle. (42) Feb.
Chattering Wheel Slip in Electric Motive Power.* G. M. Eaton. (42) Feb.
Notes on the Measurement of High Voltage.* William R. Work. (42) Feb.
Arcs in Gases Between Non-Vaporizing Electrodes.* G. M. J. Mackay and C. V. Ferguson. (3) Feb.
Municipal Power Plant at Medicine Hat.* A. G. Christie. (64) Feb. 1.
Measuring Three-Phase Power by a Watt-Hour Meter.* A. L. Temple. (64) Feb. 1.
The Predetermination of the Performance of Dynamo-Electric Machinery.* Miles Walker. (77) Feb. 1.
Means for Producing a Sparkless Break of an Inductive Circuit.* T. F. Wall. (73) Feb. 4.
The Alternating Current Single-Phase Induction Motor.* A. E. Watson. (19) Feb. 5.
The Condenser Potentiometer in High Voltage Investigations.* W. D. Peaslee and C. E. Oakes. (111) Feb. 5.
A Compact Alternating-Current City Substation.* (27) Feb. 5.
Rochester State Hospital Plant.* Thomas Wilson. (64) Feb. 8.
Cedar Rapids Power Development.* (96) Feb. 10.

* Illustrated.

Electrical—(Continued).

The Excitation of Synchronous Machines.* Theo. Schon. (27) Serial beginning Feb. 12.
Feeling Through the Fog by Wireless.* Robert G. Skerrett. (46) Feb. 12.
Meter-Test Current from Portable Batteries.* (27) Feb. 12.
Changes in Steam Station of Rhode Island Company.* (27) Feb. 12.
Data and Discussion on Efficiency in Public Utility Power Plants. Charles Brossman. (Paper read before the Indiana Eng. Soc.) (86) Feb. 16.
The Million Volt Exposition Transformer.* A. S. Lindstrom. (111) Feb. 19.
Design of Million-Volt Experimental Transformer. Guy L. Bayley. (27) Feb. 19.
Underground Distribution System at Calgary, Canada.* J. N. Lightbody. (27) Feb. 19.
Lighting a Church Auditorium Without Fixtures.* A. L. Powell and R. B. Thompson. (27) Feb. 26.
Electric Service in the Pearl of the Orient.* (27) Feb. 26.
Das Röntgenhaus des Allgemeinen Kraukenbauses St. Georg in Hamburg.* (40) Nov. 10, 1915.
Die Leitungsüberführung über die Dievenow bei Hagen-Wollen.* C. Bobnenberger. (41) Dec. 9, 1915.
Die Kalkstickstoffwerke in Odda.* Kurt Perlewitz. (41) Dec. 9, 1915.
Der menschliche Körper als elektrisches Leitungsnetz. G. Bucky. (41) Dec. 23, 1915.
Ueber willkürliche Beeinflussung der Gestalt der Magnetisierungskurven, und über Material mit aussergewöhnlich geringer Hysterese.* E. Gumlich und W. Steinhaus. (41) Serial beginning Dec. 23, 1915.
Der Betrieb von Schwachstromanlagen in Anschluss an Starkstromnetze. Fritz Schröter. (41) Serial beginning Dec. 23, 1915.
Die Bedeutung der symbolischen Bezeichnung und der Inversion für die Aufstellung des Transformatordiagramms.* Ad. Thomälen. (41) Jan. 13.
Die Wirtschaftlichkeit von Eisfabriken in Verbindung mit Elektrizitätswerken. Rich. Pabst. (41) Jan. 20.
Fernsprechleitungen kleinster Verzerrung für mehrfache Verstärkung.* H. Jordan. (41) Serial beginning Jan. 20.
Ein neuer Frequenzmesser.* W. Peukert. (41) Jan. 27.
Das Kraftwerk an den Porjusfällen.* (107) Serial beginning Jan. 29.

Marine.

The Mechanical Trimming of Coal in Ships' Bunkers.* Cecil Walter Ward. (63) Vol. 200, 1915.
The Electric Propulsion of Ships.* J. Dorman. (Paper read before the Institution of Engrs. and Shipbuilders in Scotland.) (26) Jan. 14.
Our Merchant Marine. (Report of the Boston Chamber of Commerce.) (19) Serial beginning Jan. 29.
The U. S. Naval Engineering Experiment Station.* Wm. L. De Baufre. (19) Jan. 29.
The Imperative Need for Ships Owned by Americans. William C. Redfield. (9) Feb.
Submarine Warfare.* (46) Feb. 5.
Naval Militia and Preparedness.* W. J. Willis. (46) Feb. 5.
La Stabilité des Sous-Marins.* (33) Jan. 15.
Les Tendances Actuelles dans la Construction des Sous-Marins.* (33) Jan. 22.

Mechanical.

The Effect of Chromium and Tungsten upon the Hardening and Tempering of High-Speed Tool Steel.* Prof. C. A. Edwards, and H. Kikkawa. (71) Vol. 92, 1915.
Sulphur in Malleable Cast Iron. R. H. Smith. (71) Vol. 92, 1915.
The Chemistry of Furnace Efficiency and Air Supply. C. E. Lucke and E. D. Thurston, Jr. (6) July, 1915.
Factors Governing Gas Producer Practice.* Franz Denk. (62) Serial beginning Oct. 1, 1915.
Sherardizing as a Manufacturing Problem. S. Trood. (Paper read before the Am. Foundrymen's Convention.) (62) Oct. 15, 1915.
Casting and Machinery Under One Roof. Charles C. Lynde. (62) Oct. 15, 1915.
Control of Ingot Piping and Segregation.* Henry M. Howe. (Paper read before the Am. Iron and Steel Inst.) (62) Nov. 1, 1915.
Developing Iron-bearing Materials Sinter.* Bethune G. Klugh. (Paper read before the Am. Iron and Steel Inst.) (62) Serial beginning Nov. 1, 1915.
Efficient Construction of Industrial Cars.* Charles C. Lynde. (62) Nov. 15, 1915.
Determination of Coke-Oven Heat Balance.* (62) Dec. 1, 1915.
Stack Gas for Boilers and Hot-blast Stoves. Ambrose N. Diehl. (62) Serial beginning Dec. 1, 1915.
Power Requirements for Wire Drawing.* Kenneth B. Lewis. (62) Dec. 1, 1915.

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Speeding Up Metal Stampings Production.* Charles C. Lynde. (62) Dec. 15, 1915.
Artificial Gas for High Temperature Work. E. Raven Rosen-Baum. (Paper read before the Industrial Fuel Sessions.) (62) Dec. 15, 1915.
Boiler Explosion on the S. S. *Bernicia*.* (From Report of the Board of Trade.) (47) Dec. 24, 1915.
The Lubricants of Bearings and Cylinders.* F. L. Fairbanks. (Paper read before the Worcester Polytechnic Inst.) (47) Dec. 31, 1915.
Shortening Operation Time in Automobile Shops for Increased Production.* Charles C. Lynde. (62) Jan.
Manufacturing Factors in Refractory Brick.* Robert H. H. Pierce. (Paper read before the Am. Chemical Soc.) (62) Serial beginning Jan.
Flash and Fire Tests for Lubricating Oils. (From *Lubrication*.) (62) Jan.
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Features of Rolling Mill Reversing Engines.* W. Trinks. (62) Serial beginning Jan. 1.
The Small-Shop Grinding Wheel.* John H. Van Deventer. (72) Jan. 6.
Electric Welding as Developed to Date.* C. B. Auel. (Abstract of paper read before the Inter. Eng. Congress.) (47) Serial beginning Jan. 7.
Industrial Gas: Its Services to the Nation.* H. M. Thornton. (Paper read before the Derby Soc. of Engrs.) (66) Jan. 11.
Swiss Tests of Gas-Fires.* E. Ott. (66) Serial beginning Jan. 11.
High-Pressure Distribution. T. F. Waugh. (Abstract from paper read before the New South Wales and Queensland Gas Inst.) (66) Jan. 11.
Blastfurnace Boiler Plants.* A. N. Diehl. (Paper read before the Am. Iron and Steel Inst.) (47) Jan. 14.
Cooling System for Diesel-Engine Circulating Water.* A. V. Youens. (64) Jan. 18.
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Boiler-Room Practice at Warrior Ridge. J. C. Scholl. (Abstract of paper read before the Pennsylvania Elec. Assoc.) (64) Jan. 18.
Some Principles in Industrial Lighting. J. S. Dow. (Paper read before the Illuminating Eng. Soc.) (66) Jan. 18.
Gas-Engines and Their Capacity for Dealing with Peak-Loads and Overloads. H. C. Widlake. (66) Jan. 18.
Gaseous Combustion at High Pressure.* William A. Bone. (From the *Philosophical Transactions* of the Royal Society.) (66) Jan. 18.
Empirical Design of Gas-Engine Piston Pins.* G. W. Lewis and A. G. Kessler. (72) Jan. 20.
The Commercial Motor Vehicle for Railway and Industrial Purposes.* (23) Jan. 21.
The Electrification of Isolated Factories. (12) Serial beginning Jan. 21.
The Hanyang Iron and Steel Works.* (12) Serial beginning Jan. 21.
Wire Rope: A Factor in Steel Making. James F. Howe. (Paper read before the Am. Assoc. of Iron and Steel Elec. Engrs.) (47) Serial beginning Jan. 21.
Manufacture, Strength and Use of Chains, Slings, and Other Lifting Appliances.* G. S. Taylor. (47) Serial beginning Jan. 21.
Recent Improvements in Foundry Operations. Thomas D. West. (Abstract of paper read before the Inter. Eng. Congress.) (47) Serial beginning Jan. 21.
Notes on Electric Welding Practice. (26) Serial beginning Jan. 21.
Fuel Values.* J. H. Paterson. (Paper read before the Soc. of Chemical Industry.) (57) Jan. 21.
Economic Limit of Feed-Water Heating Surface.* F. H. Rosencrants. (64) Jan. 25.
Power Plant of the Edmonton Portland Cement Co.* A. G. Christie. (64) Jan. 25.
Behavior of Boilers in Service.* J. C. McCabe. (Paper read before the Detroit Eng. Soc.) (64) Jan. 25.
The Utilization of Energy from Coal. William A. Bone. (Paper read before the Royal Institution.) (66) Serial beginning Jan. 25; (57) Feb. 4.
Effect of Feed and Diameter on Cutting Speed of Drills.* A. Lewis Jenkins. (72) Jan. 27.
New Features in Forge Shop Design.* (20) Jan. 27.
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By-Product Coking Installation in Great Britain.* Frederick C. Coleman. (45) Jan. 29.
Zeppelin Airships. (From *Yahrbuch* der Schiffbautechnische Gesellschaft.) (19) Jan. 29.
A Popular Explanation of a Rational Basis of Comparing Gas and Electric Lighting.* G. C. Shadwell. (24) Jan. 31.
Recovery of Ammonia from Waste Liquors.* E. L. Knoedler. (From *Journal of Ind. and Eng. Chemistry*.) (24) Jan. 31.

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Logical Factory Costs. W. E. McHenry. (9) Feb.
Scale *vs.* Boiler Efficiency.* (76) Feb. 1.
The Cost of Burning Brick in Scove Kilns.* Allen E. Beals. (76) Feb. 1.
Making Silica Brick.* Kenneth Seaver. (76) Serial beginning Feb. 1.
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Differential Gas Rates in Baltimore.* Douglass Burnett. (83) Feb. 1.
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Details of First Government Built Diesel Engine.* C. W. Nimitz. (Paper read before the Am. Soc. of Naval Engrs.) (64) Feb. 1.
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Turbo Blowers and Compressors.* H. L. Guy and P. L. Jones. (Paper read before the South Wales Inst. of Engrs.) (57) Feb. 4; (22) Feb. 4.
An Analysis of Oil Gas Tar. Herbert E. Brunkow. (111) Feb. 5.
Diesel Engine Practice.* J. E. Megson and H. S. Jones. (111) Serial beginning Feb. 5.
Power-House Chimney Design for Bituminous Coal.* Reginald Trautschold. (45) Feb. 5.
Pennsylvania Begins Large Coal Pier at Baltimore. (14) Feb. 5.
Comparative Efficiencies of Various Types of Air Compressors.* (16) Feb. 5.
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Naphthalene Motor Fuel. K. Bruhn. (Abstract from *Journal für Gasbeleuchtung.*) (24) Feb. 7.
Acceptance Tests of B. & W. and Stirling Boilers.* L. A. Quayle. (64) Feb. 8.
Methods of Producing Sound Steel Ingots.* Edward F. Kenney. (Abstract of paper read before the Am. Iron and Steel Inst.) (15) Feb. 11.
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Ore Unloading on the Great Lakes.* J. H. Stratton. (Paper read before the Cleveland Eng. Soc.) (19) Feb. 12.
English High Pressure Mains.* B. F. Botwood. (Paper read before the Midland Junior Gas Assoc.) (24) Feb. 14.
The Substitution of Heating Value for Candle Power as a Standard for Gas Quality. R. S. McBride. (Paper read before the Inter. Gas Congress.) (24) Feb. 14.
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Effect of Diesel Engines on Fuel Supply and Cost. S. A. Hadley. (Paper read before the Kansas Eng. Soc.) (86) Feb. 16.
Formulas and Alignment Charts for Taper Press Fits.* A. Lewis Jenkins. (72) Feb. 17.
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The New Steel Works at Lowellville, Ohio.* (20) Feb. 24.
Recent Progress in Electrical Smoke Precipitation.* F. G. Cottrell. (Paper read before the Pan-Am. Scientific Congress.) (16) Feb. 26.

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Note on the Carburization of Iron at Low Temperatures in Blast-Furnace Gases.* T. H. Byrom. (71) Vol. 92, 1915.
Phosphorus in Iron and Steel.* W. H. Hatfield. (71) Vol. 92, 1915.
The Influence of Heat Treatment on the Specific Resistance and Chemical Constitution of Carbon Steels.* Edward D. Campbell. (71) Vol. 92, 1915.
The Influence of Oxygen on Some Properties of Pure Iron.* Wesley Austin. (71) Vol. 92, 1915.
The Occurrence and Influence of Nitrogen on Iron and Steel.* Prof. N. Tschischewski. (71) Vol. 92, 1915.
Recent Blast Furnace Advancement. A. E. Maccoun. (Paper read before the Am. Iron and Steel Inst.) (62) Oct. 1, 1915.
Checkerwork for Open Hearth Furnace Use. W. A. Janssen. (Paper read before the Am. Foundrymen's Assoc.) (62) Nov. 1, 1915.
Stack Gas for Boilers and Hot-blast Stoves. Ambrose N. Diehl. (Paper read before the Am. Iron and Steel Inst.) (62) Serial beginning Nov. 1, 1915.
Melting Alloys in an Electric Furnace Unit. R. S. Wile. (62) Dec. 1, 1915.
Data on Costs of Electric Steel. F. T. Snyder. (Paper read before the Am. Electrochemical Soc.) (47) Dec. 24, 1915.
A Practical Discussion of Heat Treatment.* W. H. Phillips. (62) Jan.
Uses of Extra Coke on the Blast Furnace. Wallace G. Imhoff. (62) Jan. 1.
The Electrical Resistance of Some Heat-Treated Copper-Zinc-Nickel Alloys.* F. C. Thompson. (77) Serial beginning Jan. 15.
Blast Furnace Smelting of Cyanide Precipitate. Regis Chauvenet. (105) Jan. 15.
Modern Methods of Burning Blast-Furnace Gas in Stoves and Boilers.* A. N. Diehl. (Paper read before the Am. Iron and Steel Inst.) (22) Serial beginning Jan. 21.
Coal and Coke Efficiency in Blast Furnace Operation. Birger F. Burman. (105) Serial beginning Feb. 1.
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Die praktische Prüfung des Stahlwerksteers.* Jos. Wagner. (50) Dec. 23, 1915.
Eine bemerkenswerte Neuerung im Betriebe des Martinofens.* Karl Kniepert. (50) Jan. 13.
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Ueber den Einfluss eines Spänebrikettzusatzes auf den Verlauf des Kupolofenprozesses und auf die Beschaffenheit des erschmolzenen Eisens. (50) Serial beginning Jan. 27.
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Manufacturing British 18-Pounder High-Explosive Shells.* E. A. Suverkrop. (72) Serial beginning Jan. 6.
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German Shells and the Influence of Certain Elements on the Physical Properties of Steel. J. E. Stead. (Paper read before the Cleveland Inst. of Engrs.) (47) Jan. 28, 1915; (12) Jan. 14; (22) Jan. 14.
Industrial Lessons from the German War Machine. C. E. Knoeppel. (9) Serial beginning Feb.
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Making Five Million Primers for Cartridge Cases.* Fred H. Colvin. (72) Feb. 24.

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The Basement Rocks of the Bunter, with Special Reference to the Inundation at the Coppice Colliery. G. M. Cockin. (Paper read before the South Staffordshire and Warwickshire Inst. of Min. Engrs.) (106) Vol. 50, Pt. 2.
Forming a Shaft-Pillar in Thin Seams.* James Black. (Paper read before the Min. Inst. of Scotland.) (106) Vol. 50, Pt. 2.
Studies of the Geology of the Kent Coalfield.* E. A. Newell Arber. (Paper read before the South Staffordshire and Warwickshire Inst. of Min. Engrs.) (106) Vol. 50, Pt. 2.
The Geological Structure of the South Lancashire Coalfield.* George Hickling. (Paper read before the Manchester Geol. and Min. Soc.) (106) Vol. 50, Pt. 2.
Modern American Coal-Mining Methods, with Some Comparisons.* Samuel Dean. (Paper read before the North of England Inst. of Min. and Mech. Engrs.) (106) Vol. 50, Pt. 2.
Valuation of Anthracite Mines. R. V. Norris. (Paper read before the Inter. Eng. Congress.) (6) July, 1915.
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A New Firedamp Detector.* George A. Burrell. (57) Jan. 14.
The Pressure of Gas in Coal Beds. N. H. Darton. (From *Bulletin 72,* U. S. Bureau of Mines.) (57) Serial beginning Jan. 21.
Notes on Mine Ventilation.* John Shanks. (From *Bulletin* of the Canadian Min. Inst.) (57) Jan. 21.
Equipment of Miners' Wash and Change Houses.* Joseph H. White. (101) Serial beginning Jan. 28.
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Underground Compressor Installations in Mines.* Charles C. Phelps. (82) Feb. 12.
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Storage and Handling of Explosives in Mines. Charles E. Munroe. (Paper read before the Pan-Am. Scientific Congress.) (16) Feb. 19.
Mining in Ecuador. J. W. Mercer. (Paper read before the Pan-Am. Scientific Congress.) (16) Feb. 19; (103) Feb. 29.
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Miscellaneous.

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Engineering Societies and Publicity. C. E. Drayer. (2) Oct., 1915.
The Development and Importance of an Adequate Engineering Department for a Public Service Commission. Walter A. Shaw. (4) Nov., 1915.
Light and Illumination. Charles P. Steinmetz. (4) Nov., 1915.
The Production of Ammonia from Cyanamid. W. S. Landis. (Paper read before the Am. Inst. of Chemical Engrs.) (105) Jan. 15.
The Grading Industries.* Edward S. Wiard. (105) Serial beginning Jan. 15.
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Some Practical Pointers on Buying for a City. Fowler S. Smith. (Paper read before the City Managers' Assoc.) (86) Feb. 2.
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What Constitutes Utility Value? Philip J. Kealy. (Abstract of paper read before the Am. Elec. Ry. Assoc.) (17) Feb. 5.
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Uncertainty of Utility Valuation. T. S. Williams. (Abstract of paper read before the Am. Elec. Ry. Assoc.) (17) Feb. 5.
The Fixation of Atmospheric Nitrogen.* Robert G. Skerrett. (20) Feb. 10.
An Anemometric Paradox, A Wind Motor That is Not Affected by the Direction of the Wind.* R. Villers. (From *La Nature*.) (19) Feb. 12.
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Liquid Chlorine. G. Ornstein. (Paper read before the Am. Electrochemical Soc.) (105) Feb. 15.
Photochemistry. Harry A. Curtis. (Paper read before the Teknik Club of Denver.) (105) Feb. 15.

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Construction of Concrete Roads in Milwaukee.* H. J. Kuelling. (67) Feb.
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Methods and Costs of Construction of Concrete Pavements at Tonawanda, N. Y. A. F. Comstock. (Paper read before the Illinois Soc. of Engrs. and Surveyors.) (86) Feb. 9; (14) Feb. 5.
Reclaiming Stone from Old Macadam for Concrete Base.* Stanley E. Bates. (86) Feb. 9.
General Principles of Road Improvement. W. Muir Edwards. (96) Feb. 10.
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Essential Physical Properties of Sand, Gravel, Slag and Broken Stone for Use in Bituminous Pavements. Francis P. Smith. (Paper read before the Highway Eng. Course at Columbia Univ.) (96) Feb. 10.
Smooth Concrete Roads Produced by Accurate Headers.* (14) Feb. 12.
Concrete Road-Building Methods Yield Profits in Cash Instead of in Plant.* H. E. Breed. (14) Feb. 12.
Methods of Remedying Slipperiness on Surface Treated Macadam Roads. Burr Powell Harrison. (Abstract from paper read before the Maryland Agricultural College.) (86) Feb. 16.
Methods of Applying Bituminous Mastic Fillers for Block Pavements.* John S. Crandall. (Abstract of paper read before the Indiana Eng. Soc.) (86) Feb. 16.
Road Construction as Governed by Traffic Requirements. Robert C. Muir. (96) Feb. 17.
Present Scope for Practical Work in Improving Canadian Cities. Thomas Adams. (Paper read before the Civic Improvement League.) (96) Feb. 17.
Newark Commission Urges Importance of City Plan. (14) Feb. 19.
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Construction Methods Tested in Du Pont Concrete Road. Charles Upham. (14) Feb. 26.

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Concrete Road Conference Adopts Code of Recommended Practice. (14) Feb. 26.
Nation-Wide Canvass by Experts Sifts Out Best Methods of Concrete Road Building. (Abstract of Report to the National Conference on Concrete Road Building.) (14) Feb. 26; (86) Feb. 23.
Zum Bebauungsplan-Wettbewerb Zurichs und seiner Vororte.* Carl Jegher. (107) Jan. 22.

Railroads.

Ventilation of Tunnels and Subways in America.* Charles Samuel Churchill. (63) Vol. 200, 1915.
The Equipment of Intermediate Sidings and Single-Line Crossing-Loops, New South Wales Government Railways.* Alexander Sinclair Macdonald Caldwell Smith. (63) Vol. 200, 1915.
The Relations of the Railways and the Public. L. E. Johnson. (4) Nov., 1915.
Electrification of the Manchester to Bury Section of the Lancashire and Yorkshire Railway.* (11) Jan. 14; (12) Jan. 14; (73) Jan. 14.
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Southern Railway Dynamometer Car.* (25) Feb.
Construction of Roadbed and Track. E. A. Hadley. (Paper read before the St. Louis Ry. Club.) (87) Feb.
Efficiency and Standardization in Track Maintenance Work. S. L. Conner. (Paper read before the New England R. R. Club.) (87) Feb.
Railways of the Republic of Colombia, South America.* Jose M. Rosales. (87) Feb.
Locomotive Water and Coal Consumption.* Harold A. Huston. (25) Feb.
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Principles of Railway Block and Interlocking Signals.* Harold McCready. (Paper read before the Richmond R. R. Club.) (87) Feb.
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The Liquid Rheostat in Locomotive Service.* A. J. Hall. (42) Feb.
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Operation of Parallel and Radial Axles of a Locomotive by a Single Set of Cylinders.* Anatole Mallet. (55) Feb.
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A 12-Mile Railway Built by Hand in Five Months. (13) Feb. 3.
Drainage of Railway Roadbeds.* M. C. Blanchard. (Abstract of paper read before the Kansas Eng. Soc.) (13) Feb. 3.
Turnouts for Narrow-Gage Industrial Railway Track.* Ralph D. Brown. (13) Feb. 3.
Track Bolts of Alloy Steel. (13) Feb. 3.
Eastern and Central Time Standards in Ohio and Michigan.* Myron E. Wells. (15) Feb. 4.
The Canadian Northern Extension to Vancouver.* V. J. Boland. (15) Feb. 4.
Cost of Maintaining Private Sidings. (15) Feb. 4.
Construction Work on the Paducah & Illinois Railroad.* (15) Feb. 4.
The Government and American Railroad Needs. Otto H. Kahn. (From *World's Work.*) (15) Feb. 4.
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Government Regulation and Our Transportation Systems. Oscar W. Underwood. (Abstract of a paper read before the Am. Elec. Ry. Assoc. and Am. Elec. Ry. Mfrs.' Assoc.) (18) Feb. 5; (17) Feb. 5; (15) Jan. 11.
Mallet Compound Locomotives for the South African Railways. F. C. Coleman. (18) Feb. 5.
Some Facts About Federal Valuation of Railroads. Thomas W. Hulme. (18) Feb. 5.
Power Requirements in the Electrification of Chicago Railroads.* (Abstract from Report of the Chicago Assoc. of Commerce.) (18) Feb. 5.
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Notes on Tunnel Survey Work. M. H. Marshall. (96) Feb. 10.
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PAPERS AND DISCUSSIONS

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AMERICAN SOCIETY OF CIVIL ENGINEERS

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PAPERS AND DISCUSSIONS

DESIGNING AN EARTH DAM HAVING A GRAVEL FOUNDATION, WITH THE RESULTS OBTAINED IN TESTS ON A MODEL.

By James B. Hays, Jun. Am. Soc. C. E.

To be Presented April 19th, 1916.

Synopsis.

The following paper, though giving the theory regarding the design of an earthen dam having a gravel foundation, is intended mainly to present the results of tests on a model constructed to scale. The dam was designed to impound water for storage purposes under rather unusual conditions. A study of the subject produced little of real value in determining the action of water under these conditions.

However, this paper does not give the detailed design of unimportant features but only the general design, especially the shape and type of cross-section and the quality of the materials placed therein.

It is hoped that the discussion will bring out many interesting facts and experiences which will contribute to more rational methods of design of earth dams, or of any dams, on porous foundations.

Introduction.

At the dam site in question, a dam had been started, but was wholly unfit to sustain even a small proportion of the head of water required. The reservoir was for the storage of water for irrigation

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

purposes, and the dam was to be 110 ft. high at the maximum section. With an approximate depth of 30 ft. of material in place, and nearly the whole width of the base, a head of slightly less than 25 ft. caused water to issue in considerable quantities from the down-stream toe of the dam. This caused the people living in a small town a few miles down the river to become fearful of the results.

Several reports, made by different engineers, unanimously condemned the structure as it was being built. The bonding house backing the irrigation company failed at this time, the project was sold to satisfy judgments, and the contractors for the dam took over the proposition.

At their request, F. C. Horn, M. Am. Soc. C. E., was asked to submit a design for a dam to be built at the same site, if it could be done, in order to utilize as much of the existing structure as possible. On account of the unusual conditions—which will be stated later—it was decided to make a thorough research, to be followed by experiments and tests, in order to make certain of the design. The writer did much of the research work, constructed the model, and made the tests for, and with, Mr. Horn, which the latter has kindly made available.

General Conditions.

The stream on which the dam was being built runs southeastward, and, on the southwest side of the valley, there are high cliffs of cherty limestone near which the stream has its course. On the opposite side of the valley there are high mountains at some distance from the river. Mountain streams, rushing along at high velocity, had carried gravel, sand, and some boulders out into the valley bottom where the material was dropped, forming great cones, or fans, of very porous material. The dam site had been originally selected having one of these gravel cones as the foundation and northeast bank, this being done with only a superficial knowledge of the subsurface conditions.

When trouble was reported, work was ordered stopped by the State Engineer; then a few borings were made and test pits dug, the results of which were available for the re-design of the structure. The borings, which were made close to the center line, or axis, of the dam, show that it would be practically impossible, and useless, to reach bed-rock throughout the entire length of the dam and thereby cut off the underground flow of water.

In the subsoil investigations, a material was encountered which was called hardpan. Chemical investigation shows that there is practically no clay in this material, and, in fact, no clay in the vicinity. The material called hardpan was very fine, gritty, and angular. It was tightly packed, and formed a very dense mass.

A large quantity of this fine material was found on the surface, about a mile from the dam, and when shaken down in a glass container, packed into a very tight, dense mixture. This material is often called hardpan, but is not real hardpan, as it contains no clay.

A cut-off wall of concrete was built across the river channel, beneath which steel sheet-piling was driven into this so-called hardpan. Some of the piling was driven 18 ft. deep, and other portions sank as deep as 32 ft. with one or two blows from a 1 700-lb. hammer.

The body of the dam was being built of the same material as that composing the gravel cone at its northeast end, and, as was shown in one of the reports, nearly all the water, except flood waters, of the creek that had con-

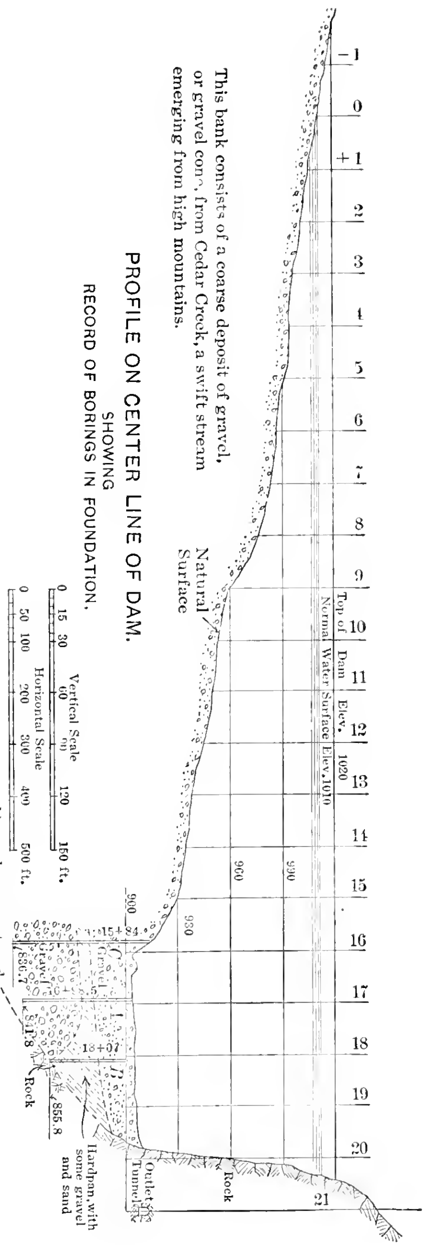

Fig. 1.

structed this cone was sinking into the gravel and reappearing at a lower point. This, it would seem, should have been an object lesson to the original locators of the site, and would indicate the conditions as to its character. However, little attention seems to have been given to the matter, and a dam was being built to hold up a head of 105 ft., to have a top width of 20 ft., with slopes of $2\frac{1}{2}:1$ up stream, and $2:1$ down stream. The down-stream toe had a gravel or loose rock drain, and the up-stream face had a concrete facing, which, for some unknown reason, did not extend to the toe of the dam.

Fig. 1 shows the results of the borings on the center line of the dam. Thus, it will be seen that the impervious stratum is a very uncertain quantity, and that bed-rock is very deep and practically impossible to reach with a cut-off wall.

General.

In looking for precedent in the design of a dam under these conditions, Mr. Horn and the writer were confronted with a lack of good material based on a systematic study of structures of this type, although several good points were obtained from some of the papers on the subject.

As these tests, experiments, and designs were made during the period from August, 1914, to August, 1915, the valuable information contained in the paper by J. B. T. Colman, Assoc. M. Am. Soc. C. E., on "The Action of Water Under Dams",* was not available. Although Mr. Colman was unable to effect a complete loss of head with his model, the writer was successful in this, and has explained the difference in construction of the two models in his discussion† of that paper, which accounts for the different results obtained. However, although the writer's experiments cover the design of the dam, as well as the study of the flow of the underground water, he believes there is much material of a different nature contained in this paper.‡

The paper§ entitled "The Bohio Dam", by the late George S. Morison, Past-President, Am. Soc. C. E., contains some interesting

* *Proceedings,* Am. Soc. C. E., for August, 1915.

† *Proceedings,* Am. Soc. C. E., for October, 1915, p. 2059.

‡ In Professional Memoirs, U. S. Engineer Corps, Vol. VII, p. 44, par. 33, there is a record of an experiment similar to a part of Mr. Colman's.

§ *Transactions,* Am. Soc. C. E., Vol. XLVIII, p. 235.

points, and the discussion on that paper brings out some good details regarding the design of the North Dike of the Wachusett Reservoir. In this structure a deep trench was excavated parallel to the axis of the dam, and in the bottom of this trench wooden sheet-piling (some pieces as long as 60 ft.) was driven. Percolation and seepage experiments were conducted with a tank similar to the one used and described by Allen Hazen, M. Am. Soc. C. E., in his percolation experiments. In the case in hand, a tank of the same style was adopted for the preliminary experiments, and furnished much valuable information to be used in the final tests. A large wooden tank was also constructed for the purpose of studying the probable percolation and seepage through the structure. In this case (the North Dike of the Wachusett Dam), the foundation, or subsoil, was not considered in the tests; thus the conditions differed from those which had to be considered in the design of the dam described in this paper.

In the North Dike there was a long, rather flat, down-stream slope, and a steeper up-stream slope. A flat hydraulic gradient, caused by the water in the reservoir seeping under the dam, called for a large quantity of material, in order to withstand the upward pressure under the down-stream portion of the dam. The dam was of such a length that the water, rising from the down-stream toe, was under no upward pressure and flowed away without disturbing the soil.

The Gatun Dam, built in connection with the Panama Canal, was designed and constructed under similar conditions, having a silty river deposit for a foundation. A flat down-stream slope causes the percolating water to travel a long distance before a free opening is encountered, thus causing the upward pressure to be consumed by friction.

In discussing the paper entitled "Dams on Sand Foundations: Some Principles Involved in Their Design, and the Law Governing the Depth of Penetration Required for Sheet-Piling",* G. E. P. Smith, M. Am. Soc. C. E., works out a very interesting theory,† showing that the creep, or total distance which the water would travel, would be increased by an amount equal to twice the length of the sheet-piling introduced. It is not stated in so many words, but the loss of velocity in traveling down one side of the sheet-piling and up the other side

* *Transactions*, Am. Soc. C. E., Vol. LXIII, p. 175.

† *Ibid*, p. 197.

amounts to the same as adding twice the length of the sheet-piling to the length of the base.

W. G. Bligh, M. Am. Soc. C. E., gives a very interesting treatment of the design of weirs on sand foundations.* His theory is that the water will follow the line of creep, along the base of the dam, down one side of the cut-off wall, up the other side, and continue along under the base to a free outlet, that is, that pressure is lost in direct proportion to the enforced line of creep. This theory gives structures of ample dimensions, as has been shown by practice, but was found to be incorrect, after due experimenting, as will be noted later.

E. A. Moritz, Assoc. M. Am. Soc. C. E., has given† the customary method followed by the United States Reclamation Service Engineers. This, it will be noted, follows the line of creep theory as described by Mr. Bligh.

D. C. Henny, M. Am. Soc. C. E., made tests‡ on different combinations of the available local materials in order to determine the tightest mass. Tests for seepage were made with many different mixtures.

In the writer's method, only one combination of materials was made, and that was done by a study of the sieve analysis curves.§ Such curves are plotted for the various materials at hand, and compared with the ideal curve for the densest mass. Experience has proved that this method gives a very tight concrete. The experiments described in Mr. Henny's paper did not cover the seepage under the dam, but adequate drainage was provided in order to forestall the danger of the down-stream bank sloughing off.

Experiments and Tests.

The foregoing sources of information are mentioned in order to show what materials were available, to give credit where similar plans were followed, and, for the sake of comparison, to state where results differed, which was largely the case.

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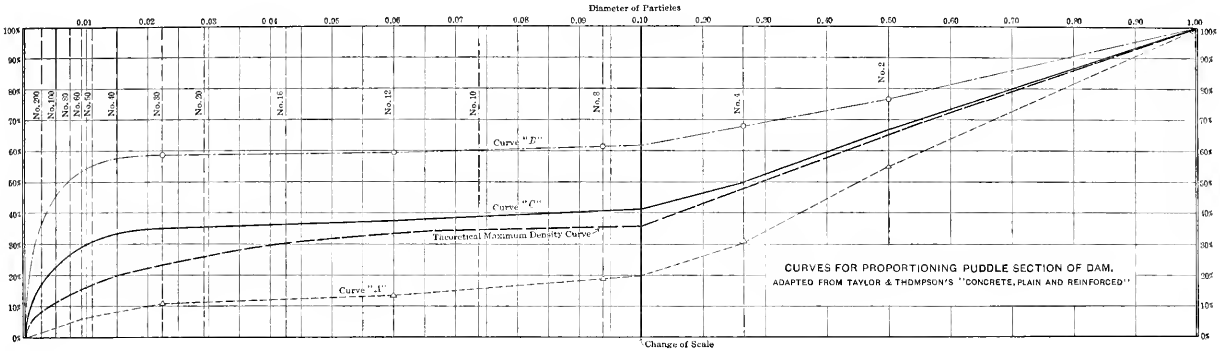
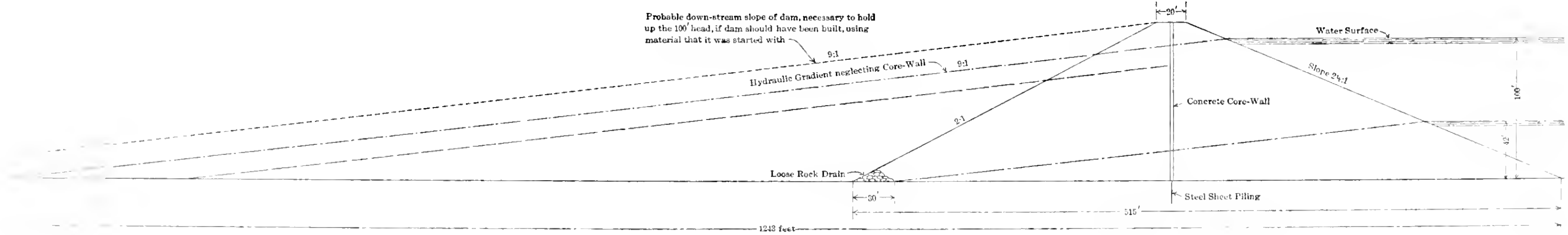
* "Practical Design of Irrigation Works", Chapter VI.

† "Working Data for Irrigation Engineers", pp. 39–40.

‡ "Two Earth Dams of the United States Reclamation Service", *Transactions*, Am. Soc. C. E., Vol. LXXIV, p. 38.

§ This method is explained in Taylor and Thompson's "Concrete, Plain and Reinforced", pp. 194, *et seq.*





ORIGINAL SECTION-AS STARTED.

The first experiments were for the purpose of determining the loss of head due to the water percolating through the various materials.

In the first test the attempt was made to determine the hydraulic gradient, or loss of head, through the coarse material constituting the foundation of the dam, and of which a part of the structure was already built. The tank had a diameter of 30 in., and a total height of 5 ft. The inside of the tank was given two coats of paint, and was then sanded in order to prevent possible seepage along its walls. Two glass tubes extending upward on the outside of the tank were connected with the inside and arranged to indicate the loss of head between two points which were vertically distant 3 ft. Fig. 2 shows the tank. A valve at the bottom held back the water until the pore spaces were completely filled; then the valve was opened, and after a few minutes the relative elevation of the water in the two tubes became constant. The difference in elevation determined the loss of head, and from this the hydraulic gradient was computed.

The initial run gave a very small loss of head; a few days later, the loss was greater and remained constant. This is explained by the fact that the material was placed in the tank in a dry state and the first application of water readjusted the finer materials into what in all probability represents the natural condition. With 6 in. of water on the soil surface, and 8 in. of soil above the upper tube, the loss of head was 1 ft. in 9.

This gravel was screened into its various sizes, and showed a very small percentage of fine material. In the upper diagram on Plate IV, Curve *A* shows this material as plotted. Fig. 3 is reproduced from a photograph of a sample of this material, and Fig. 4 shows the material as it stood in the steam-shovel pits from which the dam was being constructed and from which point the sample was taken.

Having determined the hydraulic gradient of the underground material, a trial design was made to find what dimensions would be necessary in a dam constructed wholly of this gravel. The lower diagram on Plate IV shows the dimensions, assuming that the hydraulic gradient began at the water surface on the up-stream face of the dam. The effect of the core-wall on the "line of creep" theory would be small. The section shown was deemed to be very inefficient and excessively expensive, on account of the large quantity of material to be placed. Further investigations were then made to determine how the section could be reduced.

Following out the "line of creep" theory as the one which seemed to be more nearly correct, on account of its practical success, it was decided that, if a tight material could be obtained for the up-stream section, the hydraulic gradient could be forced to begin farther up stream, and thus there would be secured the advantage of the up-stream section in reducing the upward pressure before the water reached the portion of the dam below the center line or core-wall.

As mentioned previously, a large body of very fine material was available in the vicinity. A sample of this material when analyzed gave Curve *B* in the upper diagram on Plate IV. Curve *A* showed a lack of material, which was just balanced by the excess of fine material in Curve *B*. By observation, it was determined that, for all practical purposes, the combination of these two materials in the ratio of 1:1, would give a very dense mixture which would approach closely the ideal curve. Curve *C* represents the combined material. Fig. 5 shows a sample of the fine material, and Fig. 6 shows the combined material.

TABLE 1.—Mechanical and Chemical Analyses of the Fine Material Obtained One Mile from the Site of the Proposed Dam.

Mechanical Analysis. This analysis covers only the material remaining on, and passing, the 30 mesh sieve.			Chemical Analysis. Air-dried sample.	
Mesh.	Character.	Percentage, by weight.	Constituents.	Percentage, by weight.
+ 30	Sand	7.86	Woody fiber	0.52
+ 60	"	10.06	Insoluble	52.16
+ 100	"	19.20	Silica (SiO_2)	44.48
+ 200	"	21.27	Ferric Oxide (Fe_2O_3)	2.46
− 200	Fine sand and silt	40.00	Alumina (Al_2O_3)	5.92
− 200	Clay	1.61	Lime (CaO)	18.27
			Magnesia (MgO)	5.70
			Water at 110° cent.	0.60
			Loss on Ignition (CO_2), Organic, etc.	21.58
			Undetermined	0.99
		100.00		100.00

This combined material was then tested in the tank to determine the hydraulic gradient. The head of water in the tank above the soil immediately came to a maximum, and showed only a very slight fall

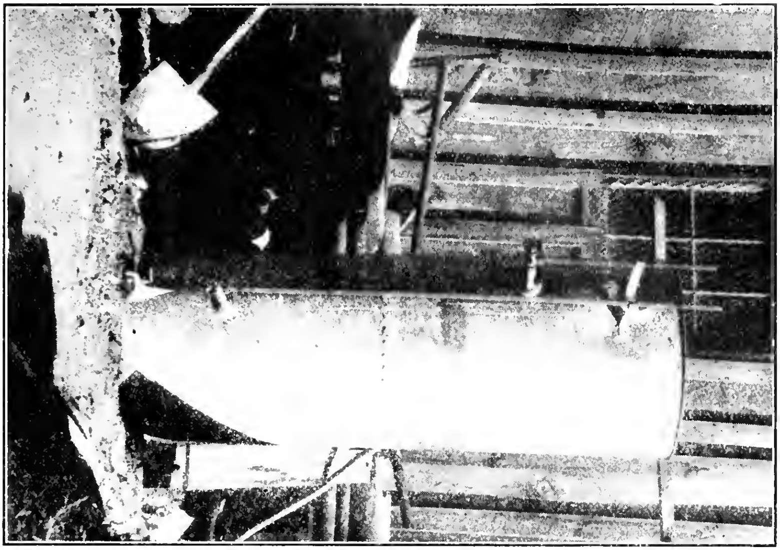


Fig. 2.—Vertical Tank for Preliminary Testing of

Fig. 3.—Near View of Gravel in Natural Position

FIG. 4.—STEAM-SHOVEL PITS FROM WHICH COARSE GRAVEL WAS TAKEN.

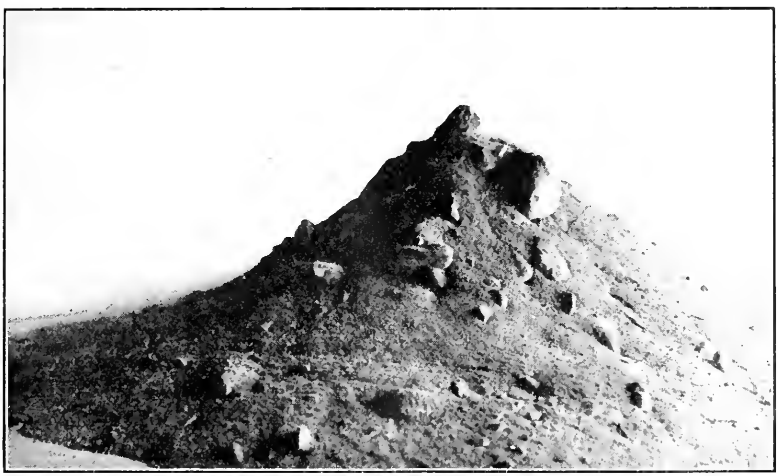


FIG. 5.—SAMPLE OF FINE MATERIAL USED TO COMBINE WITH THE COARSE GRAVEL TO OBTAIN A DENSE MIXTURE.

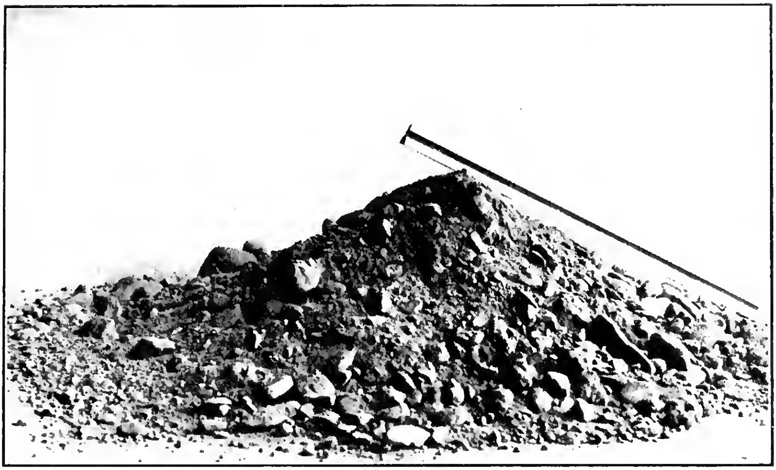


Fig. 6.—Combined Coarse and Fine Materials, Mixed in Equal Parts of Each.

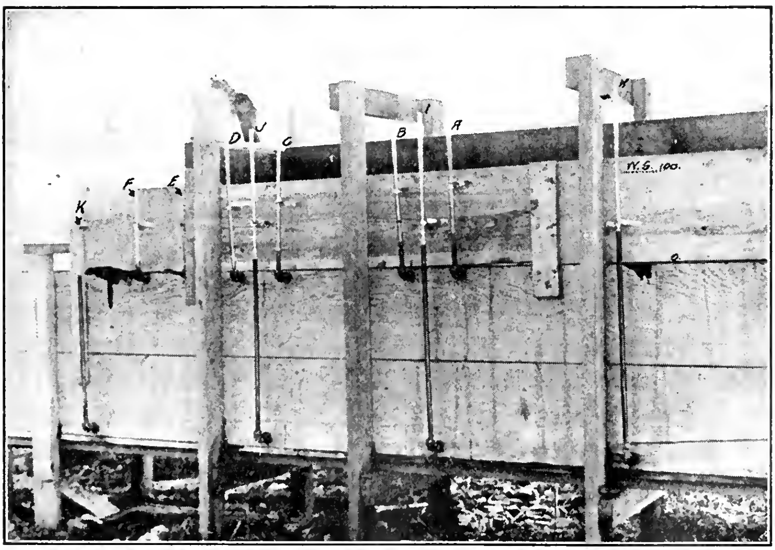


Fig. 7.—Tank in Which Final Experiments were Conducted. Full Head of Water in Tank When Photograph was Taken.

during the first day. In the morning of the second day, fully 80% of the water was still on the surface, and at the end of 47 hours both tubes were filled with water, though the valve at the base had been closed for the entire period.

On proceeding with the tests it was found impossible to determine the exact hydraulic gradient, as no water appeared in either of the tubes shortly after the valve was opened. From this it was assumed that the hydraulic gradient was not greater than 1:1, although it was evidently much steeper. Hence the design was made on this basis.

This structure was designed following out the "line of creep" theory, and it was calculated that, for a head of 100 ft. of water in the reservoir, a line of creep of 900 ft. would be necessary at the maximum section. By using the combined materials in making the up-stream section, in order to secure water-tightness, and avoid the transmission of the water pressure through the up-stream section in any great amount, it was assumed that the hydraulic gradient could be made to begin at or near the up-stream toe of the dam. Then, by the introduction of sheet-piling, the length of the base could be determined. Two rows of sheet-piling were at first suggested, and these could be made very effective by driving them in the bottom of trenches excavated for the purpose. Concrete core-walls over the piling would provide an adequate cut-off to prevent the water from passing over it. The design shown in Fig. 8 was then prepared for test. The long up-stream slope was given in order to allow the downward pressure of the water over the up-stream section to have a balancing effect on the upward pressure beneath the dam, as blow-outs would be improbable in this portion of the dam. This also gave a drier down-stream section, which meant a larger factor of safety from sloughing off and the like. A theoretical grade line is shown applied to the design.

Then, for the final tests, a model was constructed to the scale of 1 in. to 10 ft., and a large wooden tank of the dimensions shown in Fig. 8. All joints were caulked and filled with a composition filler, and then the whole interior was given two coats of a water-proof roof paint. On the second coat sand was applied, in order to prevent possible leakage along the walls. The glass tubes were placed at the points indicated by letters. They communicated by pipes with the interior of the mass at two points, and were set in from the sides of the box in order to avoid percolation along the walls. At the down-

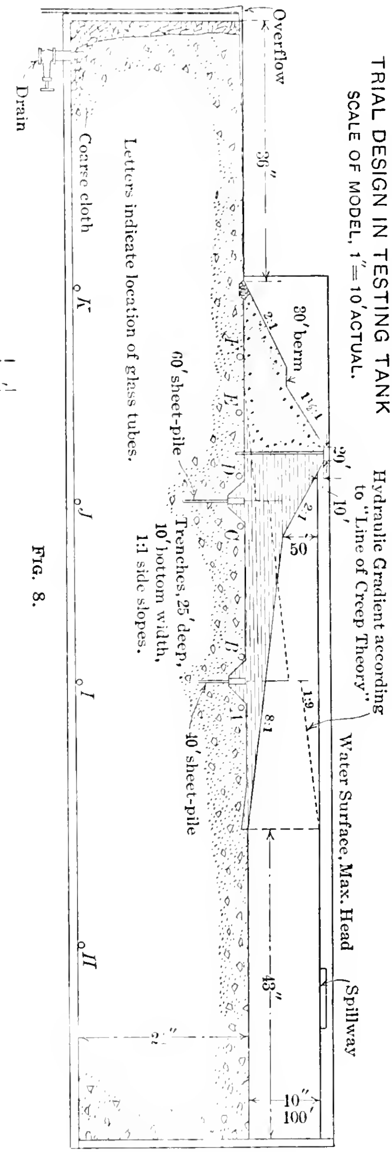

TRIAL DESIGN IN TESTING TANK
SCALE OF MODEL, 1″ = 10′ ACTUAL.
Overflow
36″
30′ berm
2:1
1½:1
20′
10′
50
Hydraulic Gradient according to "Line of Creep Theory"
1:9
8:1
Water Surface, Max. Head
Spillway
43″
10″
100′
60′ sheet-pile
Trenches, 25′ deep, 10′ bottom width, 1:1 side slopes.
40′ sheet-pile
Letters indicate location of glass tubes.
Coarse cloth
Drain
K
J
I
H

FIG. 8.

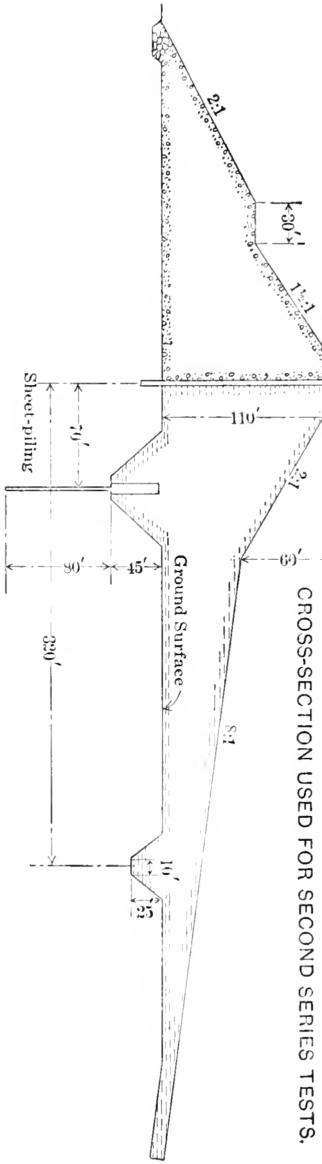

CROSS-SECTION USED FOR SECOND SERIES TESTS.
2:1
30′
1½:1
20′
110′
2:1
60′
8:1
70′
Sheet-piling
80′
45′
Ground Surface
320′
10′
25

FIG. 9.

stream end of the tank there was an overflow and also a drain. A width of 4 in. at the end of the box was filled with very coarse gravel, and this was separated from the remaining gravel by a coarse cloth. This allowed the water to travel in straight lines to the end of the box, and did not tend to force the water up to the ground surface unnaturally.

Several of the glass tubes were intended to indicate the upward pressure of the water on the base of the dam, and the others were placed along the bottom of the box to show the influence of the sheet-piling on the flow of water at the deeper points.

From the information at hand it was assumed that the bed-rock would not be more than 240 ft. below the base of the dam under the maximum section. The up-stream toe of the dam was then placed about 43 in. from the head of the box. In this way there would be plenty of room for the water to get into the soil; in other words, it was deemed necessary to avoid a narrow section or constriction through which the water would have to be forced, thereby causing a greater loss of head. A space of 3 ft. was left on the down-stream side of the dam to permit the water to come up to the surface; this was thought to be sufficient when the vertical loose-rock drain was allowed at the end.

All the subsoil material was placed dry, which made it necessary to disregard the first few readings. More than thirty readings were taken, and consisted of several runs, at four or five different heads above the dam. Records were kept of the quantity of water seeping through the gravel bed; these are given in the last column of Table 2.

Fig. 10 shows typical results obtained in the first series of tests. It will be noted that the loss of head does not follow the rule regarding the line of creep. This is shown particularly at the upper row of sheet-piling, where the loss of head is very small and not in proportion to the length of the sheet-piling. At the lower row of sheet-piling, however, near the center line of the dam, the loss of head is far greater in proportion than that at the upper row.

According to the theoretical hydraulic grade line shown on Fig. 8, the loss of head due to the upper row of sheet-piling would be, following the "line of creep" theory, 7.2 ft., though it was actually from 3.5 to 5 ft., only. The theoretical loss at the second or longer row of sheet-piling was calculated to be 9.4 ft., and the actual loss was more than twice as much, or from 19 to 21 ft.

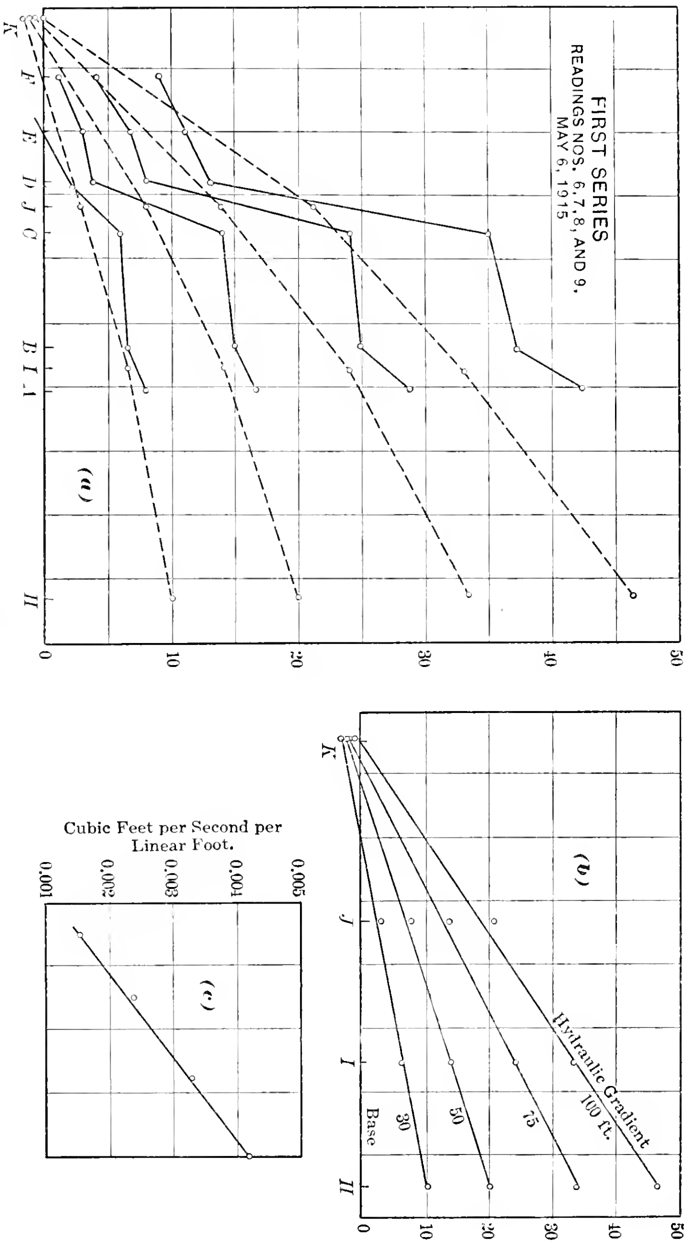

FIRST SERIES
READINGS NOS. 6, 7, 8, AND 9.
MAY 6, 1915
(a)
(b)
Hydraulic Gradient
100 ft.
75
50
30
Base
(c)
Cubic Feet per Second per Linear Foot.

FIG. 10.

TABLE 2.

No. of reading.	Date, 1915.	Time.	Head.	*A*	*B*	*C*	*D*	*E*	*F*	*H*	*I*	*J*	*K*	*S**
1	5–4	10 A. M.	100	......	44	41	16	14	11	55	41	26	2	....
2	5–5	9.30	50	......	18	17	5	4	2	23	17	10	— 2	0.00187
3	"	"	75	......	29	28	10	8	5	37	27	17	0	0.00235
4	"	"	90	......	36	34	13	10	8½	44	33	20	½	0.00395
5	"	"	100	......	41	39½	15	12	10	52	38	24	1½	0.00445
6	5–6	10.00	30	8	6½	6	2	0	0	10	6	3	— 3	0.00151
7	"	"	50	17	15	14	4	3	1	20	14	8	— 2	0.00237
8	"	"	75	29	25	24	8	7	4	33	24	14	— 1	0.00323
9	"	"	100	42	37½	35	13	11	9	46	33	21	0	0.00414
10	5–7	10.00	25	6	4½	4½	0	0	— 1	8	15	2½	— 3	0.00142
11	"	"	50	16	14	13	3½	2½	0	18	13	7	— 2	0.00223
12	"	"	75	28	24	22½	8	6	4	31	23	14	— 1	0.00310
13	"	"	90	35	31	29	10	9	6	39	28	17	0	0.00374
14	"	"	100	40	35	34	12½	10	7½	44	33	20	1	0.00395
15	"	2.20	25	6½	5	5	0	0	— 1	8½	5	3	— 3	0.00142
16	"	"	52½	17	15	14	4	3	2	19½	14	8½	— 2	0.00237
17	"	"	77½	26	23	22	8	6	3	30	21	13	— 1	0.00309
18	"	"	90	30	27	26	10	7½	5	34½	25	15½	0	0.00356
19	"	"	100	34½	31	30	11	8	6	40	29	18	0	0.00374
20	5–21	10.00	30	11	11	8	1	0	0	12	8	3½	— 5	0.00151
21	"	"	50	20	19	17	4½	2	0	22	14	9	— 3	0.00237
22	"	"	75	35	34	28	20	8	5	37	28	16	— 2	0.00323
23	"	"	90	44	41	35	14	10	7	46	34	21	— 1	0.00395
24	"	"	100	50	47	40	15	11½	9	54	39	23½	0	0.00414
25†	"	"	80	41	37	30	11	9	6	43	30	18½	— 1	....
26†	"	"	50	22	19	17	5	3	1	23	15	9	— 3	....
27†	"	"	30	11	10	8	2	0	0	12	8	4	— 4	....
28	5–25	"	32	11	10	8½	0	0	0	11	8	4	— 4	0.00114
29	"	"	50	23	20	18	4½	0	0	23	16	10	— 3	0.00216
30	"	"	75	28	‡	28	9½	6	2	37	27	15½	— 1½	0.00299
31	"	"	90	‡	41	36	13	8	5½	46	34	20	— 1	0.00340
32	"	"	100	‡	47	40	14	10	7	52	39	23	0	0.00374

* This column gives the seepage or percolation, in cubic feet per second per linear foot of model dam.

† Experiments were taken with water receding in order to compare with others; also, no percolation readings were taken.

‡ Figures excessive, due to water breaking through up-stream section of model dam.

NOTE.—The figures in this table may be converted to inches by pointing off one place and reading direct, thus 17 equals 1.7 in.

The writer wishes to state at this point that where the figures were given in feet, for convenience in stating the case relative to the actual structure, they represent actually tenths of inches on the model, that is, 19 ft. as stated above was 1.9 in. measured on the model. The figures given in the preceding paragraph were for a full head (10 in. equals 100 ft.).

The hydraulic grade line, represented by the upper row of tubes, indicated that there was an appreciable loss of head at the down-stream toe of the dam, and the lower row of tubes showed a complete loss of head at Tube *K*.

Fig. 10 (*b*) shows the hydraulic grade line of the lower row of tubes when the distance is computed from the up-stream toe of the dam to each tube directly, and it will be noted how close the hydraulic gradient is to a straight line. Tube J was evidently affected by the sheet-piling to some extent.

Fig. 10 (c) shows the seepage loss from the body of water above the dam. This subject will be discussed later.

The failure of the "line of creep" theory to work out on the model as it was expected, caused the development of another theory as to the effect and usefulness of sheet-piling as a cut-off, preventing or reducing the underground flow of water in dams designed or built under similar conditions.

The theory finally evolved was that the sheet-piling cut-off was greatly similar in its effect to a partly closed valve, wherein the water is retarded and shows a higher pressure head just above the cut-off and a lower one just below. This theory is well known in regard to the hydraulic gradient of a pipe line, and explains the inefficiency of the upper row of sheet-piling as a cut-off. Hence, in the final design of the dam, this upper or shorter row of sheet-piling was omitted, and the second row was lengthened.

The model was then reconstructed according to this idea, making the piling 12½ in. (125 ft.) instead of 8½ in. (85 ft.). Tests were then made in exactly the same manner as before, and the results obtained showed a very noticeable effect due to the increased length of sheet-piling, which bore out the theory as to effect of sheet-piling and its similarity to the partly closed valve.

Fig. 11 shows typical results taken from the last series of tests, as in Table 3. Fig. 11 (a) shows a graphical record of the readings taken on the tubes. It will be noticed that the hydraulic grade line cuts the base of the dam well up stream from the toe. Fig. 11 (b) shows the hydraulic grade line of the lower set of tubes, where the distances from the up-stream toe of the dam to each tube were plotted horizontally, to show more correctly the hydraulic grade line of the water flowing through the gravel beneath the dam. Fig. 11 (c) shows the seepage, in cubic feet per second, per linear foot of the model.

Fig. 7 shows the tank for testing the model, under a full head. The water was colored red in order to show clearly in the photograph.

The down-stream section of the dam was constructed of the same material as the foundation, in order to provide adequate drainage and

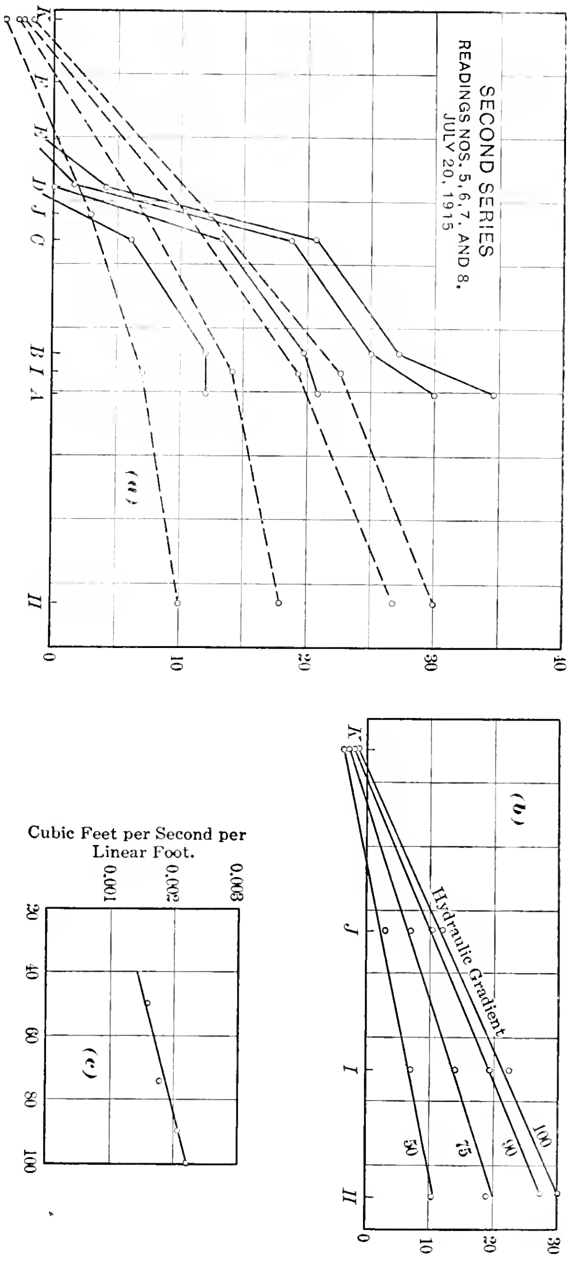

SECOND SERIES
READINGS NOS. 5, 6, 7, AND 8.
JULY 20, 1915
(a)
(b)
Hydraulic Gradient
100
90
75
50
(c)
Cubic Feet per Second per Linear Foot.
0.001
0.002
0.003

FIG. 11.

for economy. It will be noted, from the plotting of the readings of the upper row of tubes, that there was no water in this section of the dam, except possibly that due to capillary action. This contributes a great deal to the stability of the dam as a whole.

It will be noted from Figs. 10 and 11, that the water traveling at great depths is not materially affected by the sheet-piling, at any particular point; but, throughout the whole distance under the dam, the general effect is obtained. This may be attributed to the extremely slow velocity of the water.

TABLE 3.—SECOND SERIES (*a*).

No.	Date. 1915.	Time.	Head.	*A*	*B*	*C*	*D*	*E*	*F*	*H*	*I*	*J*	*K*	*S**
1	7–19	10 A. M.	50	16	13	8	0	0	0	14	9	4	—4	0.00142
2	"	"	75	27	22	16	0	0	0	23	17	9½	—3	0.00202
3	"	"	90	33	25	21	4	0	0	30	23	12	—2	0.00237
4	"	"	100	40	30	25	6	2	0	35	26	15	—1½	0.00304
5	7–20	"	50	12	12	6	0	0	0	10	7	3	—4	0.00121
6	"	"	75	21	19	13	0	0	0	18	14	7	—3	0.00174
7	"	"	90	30	25	18½	2	0	0	27	19	10½	—2½	0.00203
8	"	"	100	34½	27	21	4	0	0	30	22½	12	—2	0.00217
9	7–21	"	55	15	8	6	0	0	0	11	7	3½	—4	0.00127
10	"	"	75	23	15	12½	1	0	0	19	13	7	—3	0.00170
11	"	"	91	31	22	17	1	0	0	26	19	16	—3	0.00203
12	"	"	100	44	26	20	3	0	0	30	21	12	—3	0.00229
13	9–16	2 P. M.	30	10½	0	0	0	0	0	—3	—4	—4	—6½	0.000418
14	"	"	50	23	7	0	0	0	0	2	1	—1	—5	0.000857
15	"	"	75	40	22	7	0	0	0	8	5	3	—4½	0.00142
16	"	"	90	†	30	13	0	0	0	14	9	5	—3	0.00182
17	"	"	100	†	36	16	6	0	0	20	13	8	—3	0.00222

* Percolation in cubic feet per second per linear foot of model.

† Readings for Tube *A* were excessive, due to breaking through the thin section of model dam over that tube.

Minus readings show that the pressure, as indicated by the tubes, did not reach the base of the dam.

Figs. 10 (*c*) and 11 (*c*) show the seepage water coming through under the dam. The results show that seepage water will follow the straight-line rule, after the soil is once filled with water and a sufficient head has been reached to overcome the friction. The rate of increase of flow, for each additional unit of head applied, varies for sands and gravels under different conditions, such as porosity of sand, or gravel, character of voids, etc. As it would take a very extensive set of experiments to make any determinations in regard to the laws of seepage, the writer merely wishes to present the results so that others may use them.

In any dam, the correct place for a cut-off wall, under conditions such as these, namely, a pervious foundation, is at, or near, the up-stream toe. However, in an earth dam, it must of necessity be placed nearer to the center, or axis, of the dam. For construction reasons, the sheet-piling in this dam was placed a short distance up stream from the center line, but, at the same time, it was sufficiently far back to prevent any water from seeping through the dam to the down-stream side of the piling in any appreciable quantities.

Conclusions.

Earth dams fail from four main causes, and the writer desires to show how structures of this type may be made safe.

One cause is from overtopping, due to high waves or a flood. This is provided against by designing an adequate spillway and providing sufficient free-board. This point has not been discussed in this paper, as it is governed by local and not general conditions. The concrete core-wall was designed to extend to the top of the embankment, which would prevent waves from cutting through.

A second cause of failure is by water seeping along a conduit placed in the built-up portion of the dam. In the present case, the outlet consists of a tunnel through the rock cliffs at one end of the dam, thus eliminating this cause of failure.

A third cause, and an unseen one, is burrowing animals. Where the down-stream section is loose rock this cannot happen, and it is much the same in loose gravel.

The fourth cause is the occurrence of springs, or boils, on the down-stream face of the dam, or near it, which in turn cause blow-outs and sloughing off of the bank. A solution of this problem was the main object of these experiments. Springs, or boils, are caused by not consuming all the head of water above the dam. From the tests described herein, it is seen that either an extreme length of base of the dam must be provided, or there must be sheet-pile cut-off walls of the proper length. Where the sand or gravel foundation is of very great depth, a short cut-off would not be as efficient as in a shallower foundation, but where models are constructed, results can be obtained which enable the engineer to make correct designs better than by any other method of study.

Finally, the writer wishes to state that he claims no new discovery, but has determined a type that has solved the problem under the conditions with which he was confronted. This type has been built before, but has not been advanced together with reliable information from tests, etc. The study of the effect of the sheet-piling will undoubtedly be of value to the Profession. The application of the sieve analysis curves in combining the materials, for the purpose of determining the densest mass obtainable, has not been advanced before—as far as the writer knows—but its value as a time saver can easily be seen. Levees, canal banks, dikes, etc., may be studied in the same manner. Each design is a problem in itself, and the experiments described herein should not be misinterpreted, or applied too broadly.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

PROGRESS REPORT OF THE SPECIAL COMMITTEE TO CODIFY PRESENT PRACTICE ON THE BEARING VALUE OF SOILS FOR FOUNDATIONS*

To the American Society of Civil Engineers:

Your Special Committee, appointed "to Codify Present Practice on the Bearing Value of Soils for Foundations, and Report Upon the Physical Characteristics of Soils in Their Relation to Engineering Structures," now submits this Report of Progress. During the past year your Committee has held three regular meetings, minutes of which have been published in the *Proceedings*, and this report summarizes the results achieved.

Your Committee respectfully directs attention to the fundamental divisions of the problem: (1) The Present Practice on the Bearing Value of Soils. (2) The Physical Characteristics of Soils in Relation to Engineering Structures.

In continuing the work under the first division, your Committee here acknowledges the assistance rendered by Mr. Charles Warren Hunt, Secretary of the Society, in forwarding to all members of the Society a copy of Circular No. 1, in which information relating to tests, data, and local practice was solicited. Nearly 8 000 of these circulars were thus distributed, and, in addition, 1 000 letters were sent by the Committee to engineers especially interested. Few replies were received in response to the questions in Circular No. 1 or to the letters, and the number is totally inadequate to justify any conclu-

* Presented to the Annual Meeting, January 19th, 1916.

sions at this time. Also, it is impracticable to co-ordinate the information received, because of the absence of adopted definitions for various kinds of soils. Nevertheless, many of these replies contain valuable data which will be helpful in the formation of the Committee's conclusions to be presented with the final report.

Supplementing the rather long and formidable list of questions contained in Circular No. 1 and in the letters, individual correspondence was carried on between the Committee and the Local Associations of Members of the American Society of Civil Engineers, and has resulted in a slight addition to the data already on hand.

In consequence of your Committee's activity, the Local Associations of Cleveland, Ohio, and of Seattle, Wash., have taken action by the appointment of Local Committees on the bearing capacity of soils. Your Committee is encouraged by the interest manifested by these Local Associations. The Cleveland Association, in co-operation with your Committee, has now in use, through the engineers of the Public Works Department of that city, blanks for the purpose of collecting data in regard to the local underground formations and soil values, as used in the past and also for that which may be used in the future.

Your Committee believes that such local investigations should be encouraged and that sub-surface surveys should be carried out in all communities, particularly by the Local Associations of our Society. Your Committee will continue to collect data of tests and local practice, and abstract current literature on the subject.

Earnest and thoughtful study has been given during the past year to the original and difficult problem of soil classification for forming the basis of soil definitions and values. In order to accomplish this fundamental purpose, it was found necessary to consider the origin and processes of formation of soils, together with the physical properties that must be regarded in any scheme of soil classification. It is your Committee's view that there is no more fundamental work confronting us to-day than the classification and correlation of the physical characteristics of soils.

I. The Genesis of Soils.

In the development of the earth's crust, rocks have been formed by the aggregation and consolidation of various minerals. Those rocks in their turn have been subjected to physical disintegration and chemical decomposition by atmospheric and other natural agencies, called rock-weathering. Some of the residual products of rock-weathering are the unconsolidated clays, silts, sands and gravels, etc., which cover the surface of the underlying rock and are here defined as the soil. Thus, the soil has the same mineralogical constituents as the rocks from which it has been derived, except where chemical action has leached out the less resisting minerals.

The relative predominance of physical disintegration or chemical decomposition will vary with the locality. For instance, under the influence of moisture and heat, chemical decomposition will predominate in humid tropical regions, where the heavy clay soils occur; and physical disintegration is the dominant process in arid and arctic climates. Consequently, the properties of the soils will vary, although they may be formed from the same kind of rock. For example, the granite rocks of the humid Appalachians of the South form a fine-grained soil, and similar granites of the arid Sierras form a coarse granular product.

Physical Disintegration.—The process of physical disintegration of rock is concerned with: (1) Temperature changes, by unequal expansion and contraction of the rock minerals from heat and cold. A frequent repetition of this action, or a sudden change in temperature, causes the crumbling of the exposed surfaces of the rock. The effect is greatest where the diurnal or seasonal range of temperature is a maximum. The maximum diurnal range of temperature occurs in desert regions, and the maximum seasonal range in northern climates. (2) Alternate expansion and contraction from freezing and thawing the interstitial water in the pore-spaces of the rock. (3) The abrasive action of flowing water or wave action, when carrying sediment. (4) The action of the wind, when projecting fine soil particles against rocks. (5) Glacial action in crushing and comminuting rocks into "glacial flour", and the formation of moraines, etc., from rock débris. (6) In a limited degree, by the action of organic life.

Chemical Decomposition.—The process of decomposition is largely concerned with the chemical action of water and air. The most important chemical reactions are: (1) Hydration, (2) Carbonation, (3) Oxidation, and (4) Solution. These reactions usually cause an increase in volume of, and the disintegration of, the rock minerals. As an increase in temperature also increases the solvent power of water, a warm moist climate is most favorable to the chemical decomposition of rocks; whereas, the mechanical processes of soil formation are more noticeable in dry and cold climates.

Physical Composition.—From the physical point of view, the particles of soil vary in size and shape. The sizes of particles may be grouped tentatively in five primary grades as in Table 1; but each may be arranged in coarse, medium, and fine subdivisions.

Separations into uniform size-grades are made by the wet sifting process. Sheet-metal screens having circular openings have been adopted tentatively, and are used for the coarse grit grades and larger. Hydraulic methods are used for separating the medium grit grades and finer.

TABLE 1.

Size.	Grade.	Symbol.	Screens: Diameter of Circular Opening, in Millimeters.		Remarks.
			Passed.	Retained on.	
Shingle......	Coarse.....	Sc	64.0	32.0	Cohesionless material.
"	Medium ...	Sm	32.0	16.0	" "
"	Fine........	Sf	16.0	8.0	" "
Pebbles......	Coarse.....	Pc	8.0	4.0	" "
"	Medium....	Pm	4.0	2.0	" "
"	Fine	Pf	2.0	1.0	" "
Grit..........	Coarse.....	Gc	1.0	0.5	" "
"	Medium....	Gm	0.5	0.25	" "
"	Fine.......	Gf	0.25	0.125	Limit of porosity = 0.20 mm.
Dust.........	Coarse.....	Dc	0.125	0.0625	
"	Medium....	Dm	0.0625	0.03125	
"	Fine.......	Df	0.03125	0.01563	Limit of coagulability = 0.02 mm.
Flour........	....	F	0.01563	....	

Shape of Particles.—The particles of soil may have flat, sharp, or normal, angular, rounded, or corroded surfaces. As the largest diameter of a soil particle determines the size-grade in which it will be placed, it is evident that the shape of the particle will have considerable influence; for example, if a shot was flattened, the size of the hole through which it would then pass would be greatly increased. The presence of flat particles in soils, which have been derived from micaceous and other rocks, will differentiate the soil from the ordinary soil as indicated by the mechanical analysis.

Mineralogical Composition.—The mineralogical nature of the soil largely depends on the rock from which it has been derived, through the mechanical or chemical processes of formation. In the soils of the arid and glacial regions, a variety of minerals is usually found; and, in the humid regions, quartz and the hard minerals predominate. Such soft materials as talc, kaolinite, chlorite, and mica may exercise a decided influence on the cohesive and other physical characteristics of soils, especially in landslides or soils under pressure, and in the presence of considerable moisture.

Chemical Composition.—Chemically speaking, the soil varies with its mineral constitutents; but differences in chemical composition have a very limited physical effect, and may be practically disregarded, except, possibly, to distinguish between calcareous, alkaline, ferruginous, or silicious soils.

Physical Properties.—The physical properties which have the most important influences in soil classification are (*A*) Water content, (*B*) Texture, and (*C*) Structure.

(*A*) *Water Content.*—It has been shown by Cameron and Gallagher, in laboratory investigations, that the magnitude of any physical measurement of soil changes varies with the water content. The extent of the variation is influenced by the texture, that is, fine-texture soils are more influenced than those of coarse texture; furthermore, there is a critical water content at which the physical properties of soil attain either a maximum or minimum value.

The percentages of moisture in soils are tentatively proposed for classification purposes as follows:

Water Content.

Degree.	Percentage by weight.
Humid	0% to 5%
Damp	5% to 10%
Moist	10% to 15%
Wet	15% to 25%
Saturated	25% +

(*B*) *Texture.*—Texture refers to the relative proportion of the different size-grades of particles, and is constant. Thus, it is a property that can be used as a basis of classification. Moreover, it is an important factor on which many physical properties depend. According to texture, soils are arbitrarily separated into such classes as sandy, sandy loam, loam, clay loam, clay, etc. The presence of larger fragments of rocks and variations in the shape of particles will modify the textural class. The number of textural classes that shall be made must depend on the differences in physical properties, as influenced by the size-grades, and the extent to which it is desired to carry the divisions.

The larger textural classes may be subdivided, or adapted to any amount of detail, but, as it is probable that other soils may be found of similar mechanical composition, it is here emphasized that other properties than texture must be considered for a satisfactory classification.

(*C*) *Structure.*—Structure refers to the arrangement of the particles, and is a variable property. It may be loose and porous, or compact and impervious.

The structure of a very coarse sand or gravel cannot be materially altered. The particles, in the main, function individually; and they have a sufficient mass so that they fit together in such a way as to give about the same degree of porosity.

Clay soil, on the other hand, may fit very loosely or be very compact; the particles may be largely separated and free, or may be gathered together in groups which function together as a single large particle. There may be large and small pores, as when, in a puddled clay, the mass has been mixed together in contact with water; then the spaces between the large particles are filled in successively by smaller and smaller particles, and a very dense and impervious mass results. This condition is aimed at by the ceramist, who desires such cohesion of this product as will render it rigid and impervious, that is, a thoroughly puddled condition.

Classification of Soils.

In any study relating to natural objects, a satisfactory classification is always difficult to arrange, because the various elements merge into others by almost imperceptible gradations. No sharp lines or divisions exist, and such as are made must be more or less arbitrary. Soils have been variously classified under geological, vegetative, chemical, climatic, and other classifications, no one of which is entirely satisfactory, from an engineering point of view. Yet, accurate information in regard to the nature of soils is so fundamental that classification is necessary for interpreting their characteristics and the final solution of the problems in soil physics. For this purpose, the essential factors that produce differences in soils should be arranged in the order of their influence, and, at the same time, the ready identification of these properties in the field is of the greatest importance. At present, it is not practicable to prescribe definitely the limits of particular class groups. Future study and discussion are required to account for difference concerning the materials in any of the groups.

As rocks are the source of the soil constituents, differences in soils may be traced to two groups of factors: First, soil-forming material; and, second, the processes by which rocks have been changed into soil.

With reference to differences in soils which are due to the soil-forming material factor, these depend on the kind of rock from which the soil has been derived. This would lead to a classifying of soils as granite, sandstone, shale, slate, marl, marble, or limestone soils; but, as has been pointed out, the same kind of rock does not always give the same kind of soil, so that this one factor is incomplete in itself.

In connection with the second factor—the processes of formation—soils are classified as Sedentary Soils, which are derived directly from the degeneration of the underlying rock, and Transported Soils, which are derived from unconsolidated material and transported since it was broken down. These may be further subdivided into Colluvial (gravity-laid), Alluvial (water-laid), Æolian (wind-laid), and Glacial (ice-laid). The different agencies in the transportation of soil material determine to a large extent its character.

The system of classification to which attention is here invited is largely based on differences in the physical properties of soils.

System of Soil Classification.

(1) Soil-Forming Material and Processes.—The soil-forming material and processes of formation are here understood as the broadest bases in the physical division of soils. The Sedentary and Transported Soils are recognized as representing the first factor in the division of soils.

(*a*) Residual Soils (formed in place) include all those produced by the decay of the soil-forming material from distinctly consolidated rocks, and which has progressed so that large bodies of soil are derived therefrom. These are sometimes referred to as granite, etc., soils.

(*b*) Cumulose Soils have been formed in place from the accumulation of organic matter. Their engineering significance is quite limited. .

(*c*) Colluvial or Gravity-laid Soils are formed by the accumulation of soil material by gravity without the appreciable co-operation of any other force. They include cliff and talus débris, and accumulations on hillsides and undulating uplands, etc.

(*d*) Alluvial or Water-laid Soils are formed by the sedimentation of soil material, transported, sorted, and deposited entirely by water, whether laid down by rivers, lakes, or oceans. They include river alluvium loess, and adobe in part, estuarian clays, salt marsh, and swamp deposits, sea beach sand, etc.

(*e*) Æolian or Wind-laid Soils are formed by the transportation, sorting, and depositing of soil material by wind. They include sand dunes, of lakes and sea shore, loess and adobe in part, volcanic dust, etc.

(*f*) Glacial or Ice-laid Soils are formed by pulverization, transportation, mixing, and depositing of soil material by glacial action. They include glacial drift, till or boulder clay, morainal deposits, etc.

(*2*) *Water Content.*—The water content of soils, when determined as "moisture equivalent", or by evaporation, in percentage of the weight of a unit volume, is recognized as the second important factor in the division of soils.

(*3*) *Special Condition.*—This includes a group of properties, any one of which may be used as the basis for the third factor in the division of soils. These properties may be:

(*a*) Mineralogical.—When the physics of the soil are affected by the mineral constituents;

Or as of a calcareous, alkaline, silicious, or ferruginous nature.

(*b*) Structure.—When open or porous; compact or impervious.

(*4*) *Texture.*—The texture of the soil material is recognized as the fourth factor in the division of soils. The percentages of size-grade limits have yet to be quantitatively determined.

The names proposed for the foregoing factors in the division of soils are as follows:

(1) Source of soil material........................Group
(2) Water content..............................Series
(3) Special conditions..........................Phase
(4) Texture ....Class.

The combination of these factors will determine the type, which is the unit of soil classification. The soil type may be defined as including all that soil material which is approximately alike in source of soil material, moisture content, special condition, and texture.

Your Committee does not consider that this is the final classification, but it is submitted with the view of discovering its weaknesses. Nevertheless, it is believed that it is the proper basis on which any soil classification must be formulated.

Table 2 shows the classification proposed.

The study of the physics of soils includes a certain amount of laboratory investigation, and your Committee, having found that the procedure in use by agronomists is not satisfactory, it became necessary to undertake much experimental and original work. A great deal of time and expense has been devoted to these studies, which include: the sizes, gradation, and mineralogical composition of soil particles; the proper and best form of screen; the development of inexpensive apparatus for field and laboratory use for soil analysis; the theory and design of centrifugal elutriation methods, etc., etc. This work has not progressed sufficiently to make a report at this time. Developing standard methods for laboratory procedure is necessarily quite expensive and time consuming, so much so, that your Committee was obliged to curtail its work on account of the exhaustion of the funds available. In this connection your Committee expresses a deep appreciation for past support and encouragement by the Board of Direction, without which the work already accomplished would have been impracticable.

During the coming year your Committee expects to complete a standard method of laboratory procedure, and carry out a number of mechanical analyses for the purpose of determining the textural limitations for certain classes of soils, etc.

Last year your Committee, acting through the Technology Branch of the Carnegie Library of Pittsburgh, Mr. Harrison Craver, Librarian, and Mr. J. C. McClellan, Technology Librarian, submitted nearly 400 references in a bibliography of the "Physical Properties and Bearing Value of Soils". This work has been continued, and about 500 references have been added, which will be classified and published with a later report of your Committee.

Your Committee has been in close co-operation with, and now acknowledges the fundamental and important work which has been undertaken by, the United States Bureau of Standards, of Washington, D. C., Dr. S. W. Stratton, Director, without expense to the American Society of Civil Engineers. The scientific report from the sub-committee of this Bureau is appended herewith, as information indicating the scope of the problem.

TABLE 2.—SYSTEM OF SOIL CLASSIFICATION.

<table>
<tr><th>Divisions.</th><th>Factors.</th><th colspan="11">THE SOIL.</th></tr>
<tr><td rowspan="4">Group.</td><td rowspan="4">Derivation of Material.</td><td colspan="5">SEDENTARY.</td><td colspan="6">TRANSPORTED.</td></tr>
<tr><td colspan="4">RESIDUAL.</td><td>CUMULOSE.</td><td colspan="3">WATER-LAID OR ALLUVIAL.</td><td>Gravity-laid or colluvial.</td><td>Ice-laid or glacial.</td><td>Wind-laid or aeolian.</td></tr>
<tr><td rowspan="2">Igneous rocks, etc.</td><td rowspan="2">Sandstone, quartzite, shale, slate, etc.</td><td rowspan="2">Limestone, marble, etc.</td><td rowspan="2">Unconsolidated, marl, clays, sands, gravel, etc.</td><td rowspan="2">Peat, muck, and swamp, in part, etc.</td><td>Alluvial (streams).</td><td>Lacustrine (lakes).</td><td>Marine (oceans).</td><td rowspan="2">Talus and cliff débris, hillside accumulations, etc.</td><td rowspan="2">Morainal material. drumlins, boulder clay or till, drift, etc.</td><td rowspan="2">Sand-dunes, loess and adobe, in part, volcanic dust, etc.</td></tr>
<tr><td>Recent alluvium, loose and adobe, in part, etc.</td><td>Marsh and swamp, terrace and beach deposits, etc.</td><td>Salt marsh, swamp deposits, sea beach sands, estuarian clays, etc.</td></tr>
<tr><td>Series.</td><td>Water content.</td><td colspan="11">Humid 0-5%
Damp 5-10%
Moist 10-15%
Wet 15-25%
Saturated 25%</td></tr>
<tr><td>Phase.</td><td>Specific conditions.</td><td colspan="11">Structure — Porous, impervious, etc.
Mineralogical — Micaceous, talcose, etc.
Calcareous, alkaline, ferruginous, silicious, etc.</td></tr>
<tr><td>Class.</td><td>Texture.</td><td colspan="11">Shape of particles. — Flat, sharp, or normal, angular, rounded, corroded surfaces, etc.
Physical composition. — (Quantitatively fixed.)
Fragments of rocks. — Shaly, slaty, etc.</td></tr>
</table>

Type is the combination of Group, Series, Phase, and Class:

EXAMPLE. Group = Residual.
Series = Moist.
Phase = Micaceous.
Class = Clay.
} Describing a residual, moist, micaceous clay.

In view of the basic nature of the problem, any estimate of the time of completion or cost of its undertaking is merely guesswork; but, if continued, the Committee feels justified in anticipating that its work will prove helpful to the Engineering Profession in interpreting soil values, and bringing this neglected phase of engineering science to a basis equivalent to that of any other branch. However, this is dependent on the wishes of the Society and the support of the Board of Direction.

Respectfully submitted on behalf of the Committee.

ROBERT A. CUMMINGS, *Chairman.*

JAN. 18, 1916.

COMMITTEE:

WALTER J. DOUGLAS,
EDWIN DURYEA, JR.,
E. G. HAINES,
ALLEN HAZEN,
J. C. MEEM,
ROBERT A. CUMMINGS.

APPENDIX

U. S. BUREAU OF STANDARDS SUB-COMMITTEE: REPORT ON EARTH EXPERIMENTS AND APPARATUS.

A sub-committee was appointed by the Director of the Bureau of Standards to co-operate with the Chairman of your Committee in the work of investigating the physical laws of earths under strain when they are graded according to the proposed tentative classification. A review of existing literature by this committee showed that there has been little experimental investigation of a systematic character performed in the past along this line. The factors heretofore determined are too few and their range of variation is too large for these to be of much utility in an adequate handling of the problems under consideration. If there is to be any hope of ultimate success in this field of endeavor, the committee felt that its investigation must be quite fundamental in character, in that an attempt should be made to discover the true weights of influence of each of the different variables which enter the mechanics of earth resistance, and the relations existing between these variables. Admittedly, much of the practical information earnestly desired by engineers at the present time can only be gotten by statistical analyses of a large number of field observations on piles, dams, foundations, and other structures. On the other hand, if such observations are to have a scientific value in deducing empirical or rational laws, the investigations must be preceded by appropriate systematic laboratory work taken up in the light of rigorous and consistent mechanics.

The purpose of the committee to the above ends is to discover to what extent the practical laws of earth resistance are possible of formulation. A rather considerable range in the moduli and other coefficients to be determined, it is believed, may be expected at best. Assuming, however, that the mechanics of fluid and elastic media is amply well grounded and sufficient to cope with any experimental phase of the investigation that may arise, if the determining conditions may be fairly stated or realized experimentally, a large number of tests already have been made and will be continued in the future to ascertain what types of equilibrium exist and are possible in different classes of earths, granular, argillaceous, and others, as classified by your committee. An effort is being made to determine what are the elastic and other coefficients that must enter; the laws of variation of stress and strain functions; what, moreover, are the influences of interstitial matrices of plastic material in the voids, water content, etc. An abstract of the work thus far performed will be given.

Attention was first given to the selection of an appropriate earth gauge, precise and simple of construction, which would be applicable, not only to any later tests on laboratory piles or walls, but also in studying experimentally the pressures in the cylinders of clay-working machinery, and in determining the general laws of failure of materials, etc. The types of gauges considered were: (1) the plug or piston type, as used by Goodrich in his conjugate pressure determinations; (2) the corrugated gauge, as used by Emery in his testing machines, and recommended for earth pressure determinations by Bell in England; (3) piezometer or pressure bulbs as used in certain volumetric analyses by physicists; (4) water and mercury gauges, as used by Wilson and others; (5) flat diaphragm types, in which the deflection could be determined as a function of pressure and form variables by suitable measuring devices.

A $2\frac{1}{2}$-in. piston gauge of the Goodrich type offered many advantages to the experimenters. In his tests, Goodrich was able to attain a minimum displacement varying from 0.001 to 0.0002 in. depending on the sound intensity of an electric buzzer. In the preliminary tests of the committee with a gauge of this type, it was found possible by appropriate mechanism to reduce this displacement to less than 0.00005 in. The gauge was rather reluctantly abandoned finally for standard test purposes, however, on account of some synchronism of the multiplying device in operating the testing machine used in applying pressure to the earth, but chiefly for the reason of the pressure discontinuity (or singularity) introduced at the rim of the piston as it moves under pressure. Although this is eliminated in the corrugated diaphragm type, and the pressure changes gradually as the diaphragm depresses, it was believed, from later considerations, that there was the possibility of too much dilatation of the earth in that type, although the magnification of the deflection is very convenient in observing. The corrugated gauges were abandoned. Mercury and water types, though very sensitive to pressure determinations, were reported in the investigations of another laboratory to be also very sensitive to temperature changes, and to require continual corrections during experimentation.

It was decided, finally, to confine the work of the committee to the flat diaphragm and piezometer types. Experiments under a variety of conditions, which will be outlined later in brief, have been made with the type of gauge shown by (*a*) Fig. 1, the diaphragms being of Brown and Sharp, ground, spring steel in thicknesses of $\frac{1}{64}$, $\frac{1}{16}$, $\frac{3}{32}$, and $\frac{1}{8}$ in., the gauge parts being otherwise of carefully finished brass. To avoid the difficulties of the re-entrant angles common to most gauges, and especially the corrugated type, gentle easement curves of recession from the diaphragms were used at first in the trial gauges.

In the tests for efficiencies thus far made the gauge was placed in the bottom of the cylinder base, as shown by (*a*) Fig. 1. The designs of the apparatus, however, include various other positions conformable to the needs of conjugate pressure determinations (not shown in Fig. 1). Besides the gauge calibrations and experiments, the purpose of the apparatus was to afford opportunities for studying the laws of distribution and intensities of the lines of force under various superimposed load conditions, as in problems of an analogous class in induced electrical distributions. This portion of the investigation is in several respects a logical continuation of the experimental work of this character already taken up by Tresca in France,* and later carried out by Dr. Wilson† in England and Goodrich‡ in America in different phases. The loads used in supplying pressure on the earth were applied through the medium of a 200 000-lb. testing machine (Fig. 4) the variables tentatively taken being: (1) type of earth; (2) applied pressures, 0 to 80-100 lb. per sq. in.; (3) piston area; (4) height, y, of earth in cylinder; (5) mass, density, volumetric strain; (6) time rate of load; (7) wall frictions; (8) earth frictions and coefficients; (9) water content, etc.

Calibrations of the gauges in position under oil pressure showed that they were thoroughly dependable as hydrostatic devices, the result of repetition of the tests showing agreement to a unit of the third significant figure. In the calibrations, independent and simultaneous pressure determinations were made with an ordinary Ashcroft pressure gauge which had been carefully calibrated under repeated loads on an Emery tester, and the results compared with the readings on the testing machine beam. The diaphragm gauge deflections were measured with an Ames' dial reading direct to 0.001 in. and by estimation to 0.0001 in.

In applying such a gauge to earth pressure determination, a group of phenomena must be considered. The assumption would appear to be a valid one, however, that if normal lines of force end on the gauge diaphragm, the observed pressure should be identical with that found under hydrostatic conditions when the deflections recorded in the two cases are the same; but, if the recorded pressure is to be representative of the mean pressure in the region of the gauge, it is important that the earth remain essentially homogeneous. For example, if the portion of earth just over the gauge changes its density or other properties, or, if there are induced restraining shears brought into play as the gauge deflects, the pressure reading is not indicative of the mean pressure on the adjoining wall in the vicinity of the gauge. The difficulties which are to be met and overcome will be described.

Experiments with sands of different coarsenesses of lime, silica dust, and plaster of Paris, all showed the importance of obtaining: (1) the

* "Mémoire sur l'Ecoulement des Corps Solides" (1865), by H. Tresca.

† "Experiments on Conjugate Pressures in Fine Sand * * *", by Dr. George Wilson, *Minutes of Proceedings*, Inst. C. E., Vol. CXLIX, p. 208.

‡ "Lateral Earth Pressures and Related Phenomena", by E. P. Goodrich, M. Am. Soc. C. E., *Transactions*, Am. Soc. C. E., Vol. LIII (1904), p. 272.

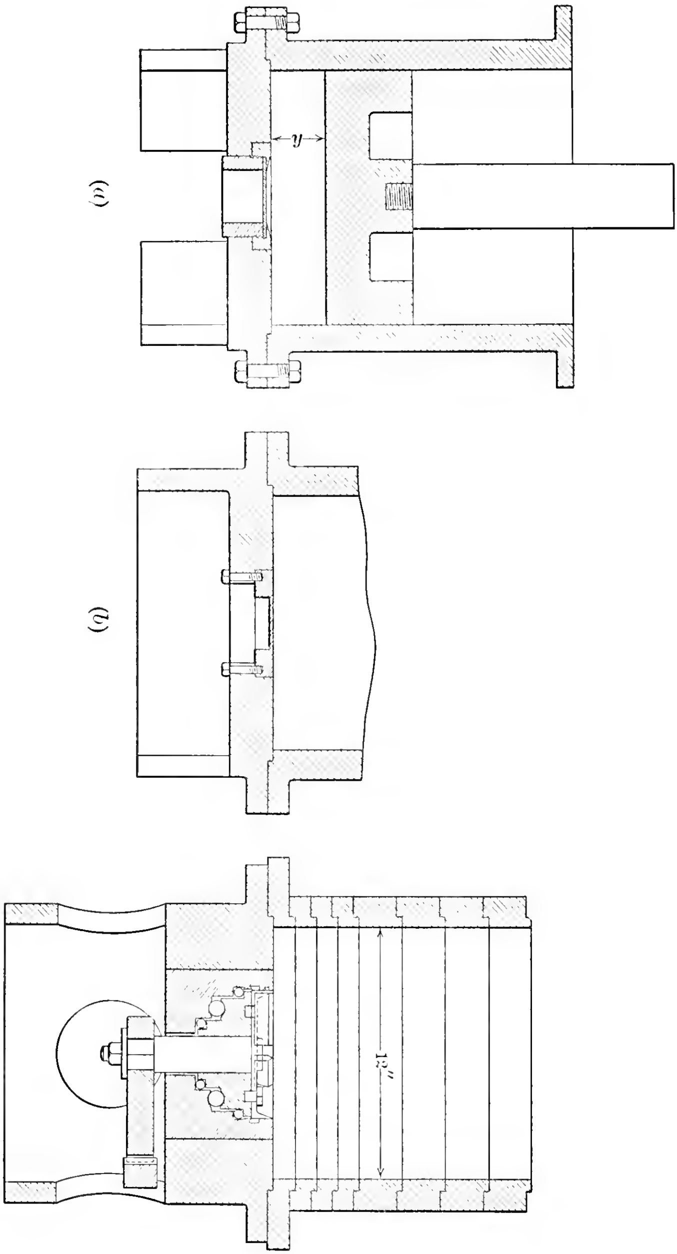


FIG. 1.

same lay of earth in each experiment; and (2) a uniform contact and pressure on the piston. In the first case the expedients of dropping the material from the same heights, subjecting the earth to known impactions, ramming, etc., were tried in particular sets of tests. For the second, a rotary screed was used in leveling the earth before the application of the piston. The earth finally was confined to one type, a 20-30 Ottawa sand, oven-dried before insertion, and a study made of the results. It was found that the load-pressure curves are all of the form,

$$w = a_1\, p + a_2\, p^2 + \ldots\ldots$$

where w is the load on the beam of testing machine, in pounds per square inch, and p is the pressure registered on the gauge, a_1 and a_2 being constants. There are usually critical regions in the vicinity of 30 lb. per sq. in. of load. For smaller values of y, the depth of earth being 1 in. or less, maximum pressures are recorded, being about 90% of the corresponding hydrostatic pressures, the friction of the walls of the cylinder for the low heights being neglected. The range of variation from the mean large is ± 20 per cent. As the distance, y, is increased, and more lines of force fall on the walls of the cylinder and fewer on the gauge, the wall friction being increased proportionately, there is a corresponding falling off from hydrostatic pressure. The minimum range of variation from the mean is some 6 to 8% in the region of $y = 4$ to 6 in. The pressure is about one-half of the hydrostatic.

The need of certain modifications in the apparatus appeared to be shown by these results, and a brief reference to the theoretical laws governing will be made in explaining these. The committee feels that if the range of departures from the mean for a particular type of earth may fall short of those for steel from the same heat, on the other hand, they should not exceed those for cement or concrete, etc., if the results of an investigation are to possess any particular practical value for application to engineering problems.

Theoretical considerations based on the hydro-dynamical equation of continuity,

$$\left[\frac{d\,V}{d\,t}\,\frac{1}{V} = -\,\frac{d\,\rho}{d\,t}\,\frac{1}{\rho} = \left(\frac{\delta\,u}{\delta\,x} + \frac{\delta\,v}{\delta\,y} + \frac{\delta\,w}{\delta\,z}\right)\right],^{*}$$

show that the time rate of change of density (or volume) is a function of the density (or volume) and volumetric impression per unit of volume. Compressive density changes in the sand (not the particles) are evidently taking place during the earlier loading, as is indicated later. In general, if a closed surface is taken to include a particular portion of the medium, there is a flux of matter through this surface, either on account of the inherent compressibility of the material, as a

* See Webster's "Dynamics", p. 498; or Lamb's "Hydrodynamics", p. 7.

whole, or because the matrix surrounding particles is becoming more compact in the voids. Again, in the case of granular materials, the elementary masses resist changes of form with a force which is a function of the mean stress, that is, the mean of the three co-ordinate pressures on the elements, the modulus of rigidity varying with this mean pressure. This law apparently accounts for the slope of the curve being relatively constant after any period of condensation is passed. In ordinary structural materials, of course, such as steel, concrete, or other solid materials, a region of impaction of particles and density changes is not considered, experimenters taking their initial loads of tests usually slightly above the region of impaction or what amounts to this, so as to obtain the stress as a linear function of strain, in accord with Hooke's Law. It is in general necessary to consider such changes. Accordingly, if the time is not to enter as a major variable, some practical method of preliminary impaction of an earth appears desirable. If the material is dropped from known heights, on the contrary, density time changes, it is believed, must be taken into account during tests, the loading being continuous. Although this was tried in a number of cases, it is found difficult at the present time to measure the volumetric compression or dilatation very closely, on account of the perturbing effect of wall friction, and the law of variation of this friction requires special investigation. Ramming of the earth, according to the experiments of Dr. Wilson, though reducing the range of departures, does not readily admit of standardization for studying a large series under the same experimental conditions. Simple practical methods must be devised.

Another difficulty, of the same type as described, arises. There must be, for standardization purposes, assuming that the earth "lay" is quite homogeneous after some standard method of impaction has been found, a uniform contact of the actuating piston on the mass (or the law of distribution known). The experimenters found that they could easily control the intensity of the lines of force on the diaphragm by taking arbitrary lays of earth or by tracing small grooves on the upper surface, etc. Experiments with the earth in glass cylinders, where the action of open gelatine capsules immersed in different arrays could be studied, showed laws conformable to the above. The flux into the voids is rather fast for the earlier loadings, but is considerably reduced for the higher pressures. The granular material first fluent tends to approach the solid behavior, with increment of stress. Assuming an ordinary U-tube of force in the mass, for example, a small column of earth in one arm will balance a much higher column in the other or effort arm on account of the influence of molecular friction,

$$\left[p_1 = \left(\frac{1 - \sin.\ \phi}{1 + \sin.\ \phi}\right) p_2\right],$$

according to the ordinary law of Rankine, as used by engineers.

The committee has not fully decided at this time on a standard method of laying the earth, and is still studying this point carefully. It was found, however, that by laying known masses in layers of about $\frac{1}{4}$ in. and subjecting these to known increments of pressure, according to a definite law, the final height of the mass could be duplicated with small departures from the mean, and this expeditiously enough for laboratory purposes. This method has seemed preferable to ramming in layers. Moreover, striking off at the top of a box or cylinder is found much more satisfactory than the rotary screed. Accordingly, the cylinder has been re-designed, according to the outline of Fig. 1 (*c*), to meet these exigencies. Particular values of the variable, y, can be chosen, then the earth can be struck off at this height, and the piston applied with a very uniform contact.

Referring now to the action of the gauge itself: The falling off from full hydrostatic pressure, the piston frictions being taken in the case of earth of the same amount, as with oil, is accounted for, it is believed, by the following considerations: Assuming, first, that there is a possible means of recording pressures without relative depression of the diaphragm from the plane of the wall, the density of different columnar elements and their compression moduli being taken as uniform at all portions of the base of the cylinder, the stress distribution over the diaphragm in a gauge with a reveal will be different from that on the adjoining portion of the base for the same piston displacement, the theoretical relation between the pressures being $p_1 = \frac{l_2}{l_1} p_2$, where p_1 and p_2 are the loads per unit of area on the diaphragm and adjoining bases, respectively, and l_1 and l_2 are the corresponding heights of the columnar elements. As in most gauges having a reveal, such as in that of the committee, already described, the depression below the base or wall is about $\frac{1}{4}$ in., the stress on the diaphragm will then fall off theoretically from hydrostatic pressure in accordance with the above law. For example, when the piston is 1 in. above the base, $p_1 = \frac{1}{1.25} p_2 = 80\%$ of p_2, theoretically. This consideration shows then that the gauge diaphragm should be in the same plane as the adjoining wall.

Although Tresca, in 1865, assumed that the "central cylinder" of material over the orifice, in his ceramic-paste and flow-of-solid tests, possesses the same density as the surrounding mass, the committee is of the opinion that this is an untenable assumption in the case of granular earths and perhaps others, however correct it may be in the case of solids, liquids, or pastes. In the case of so-called incompressible soils, such as compacted sand, grains in normal array, etc., a slight dilatation in the "central cylinder" over the diaphragm will cause some, perhaps considerable, variation in pressure from that of the surrounding mass. Experiments also show that compressed sand possesses comparatively little resilient power, after the load is removed. The committee, therefore, feels disposed to avoid the use of rubber diaphragms, corrugated gauges, steel plates, or other flexible types, wherever the displacement may be considerable, for measuring pressures in standardization tests, and has re-designed the gauge, as shown by Fig. 1(*b*), to meet the difficulties encountered. The modified gauge is turned out of a single piece of tool steel, has no reveal or re-entrant angles, and will have a diaphragm not exceeding approximately $\frac{1}{8}$ in. thick, so that the deflections will only be a few hundred thousandths of an inch in a range of pressures from zero to 100 lb. per sq. in. A simple device for measuring deflections, reading direct to $\frac{1}{100\,000}$ in., and by estimation to $\frac{1}{1\,000\,000}$ in., will be used in observing. (This is not shown by Fig. 1.) The effect of shearing restraint on the "central cylinder", and sudden discontinuity in pressure at the rim of a piston gauge is thus nearly eliminated. Opportunities for lost motion at the diaphragm, or in "seating" the two plane surfaces, is prevented by connecting the gauge to the base or wall by $\frac{3}{8}$-in. cap-screws.

As soon as the committee has perfected a practical method of studying earths under definite conditions which can be standardized and duplicated in the laboratory—and this can only be done after careful preliminary tests are carried out in the manner described—it will be able to proceed in a more systematic manner with its investigation, taking up different earths according to a scale of gradations of particles or other classification, water content, etc. The points brought up thus far are given more or less fully to show how important is felt to be the need of a reliable standard earth-gauge in all earth-pressure determinations, if results of observations are to be at all trustworthy.

The other apparatus designed by the committee has been constructed, and a number of tests have been made. This apparatus will be described.

In view of the fact that the law of variation of shearing and frictional stresses is of vital importance in this investigation, the apparatus shown by Figs. 1 and 2 was constructed for the purpose of making a systematic study of classified earths, when tested according to a standard method, for observation of the phenomena of internal friction.

The ball-bearing turn-table of this apparatus (Figs. 1(*c*) and 3) is constructed of tempered tool steel, the ball-race is ground and the balls are fitted for the true running of the bearing. The larger three balls (4 in. in diameter) support the bearing vertically; the smaller balls ($\frac{1}{2}$ in. in diameter) serve to take up the bending moment occurring when a torque is applied to cause turning against the resistance of

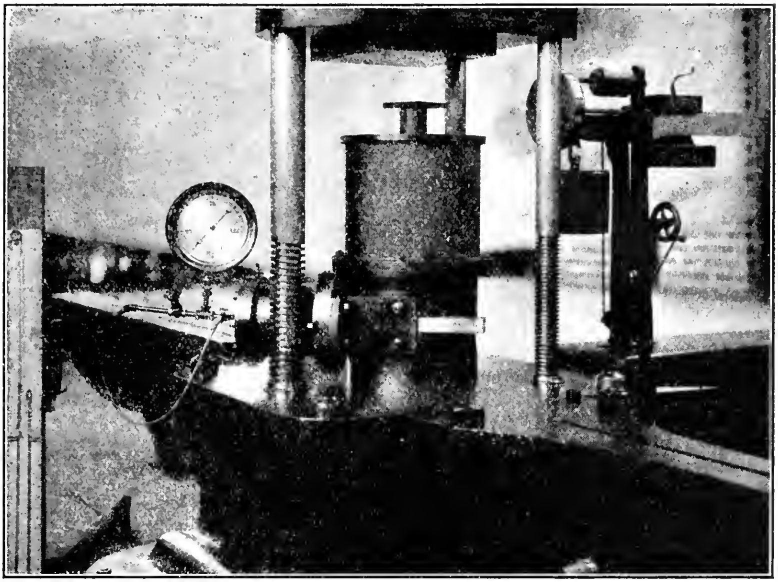


FIG. 2.—APPARATUS FOR MEASURING COEFFICIENT OF FRICTION OF DIFFERENT SOILS.

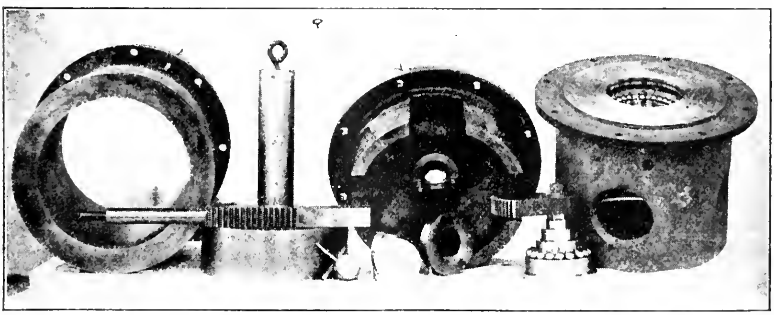


FIG. 3.—PARTS OF FIG. 2 BEFORE ASSEMBLY.

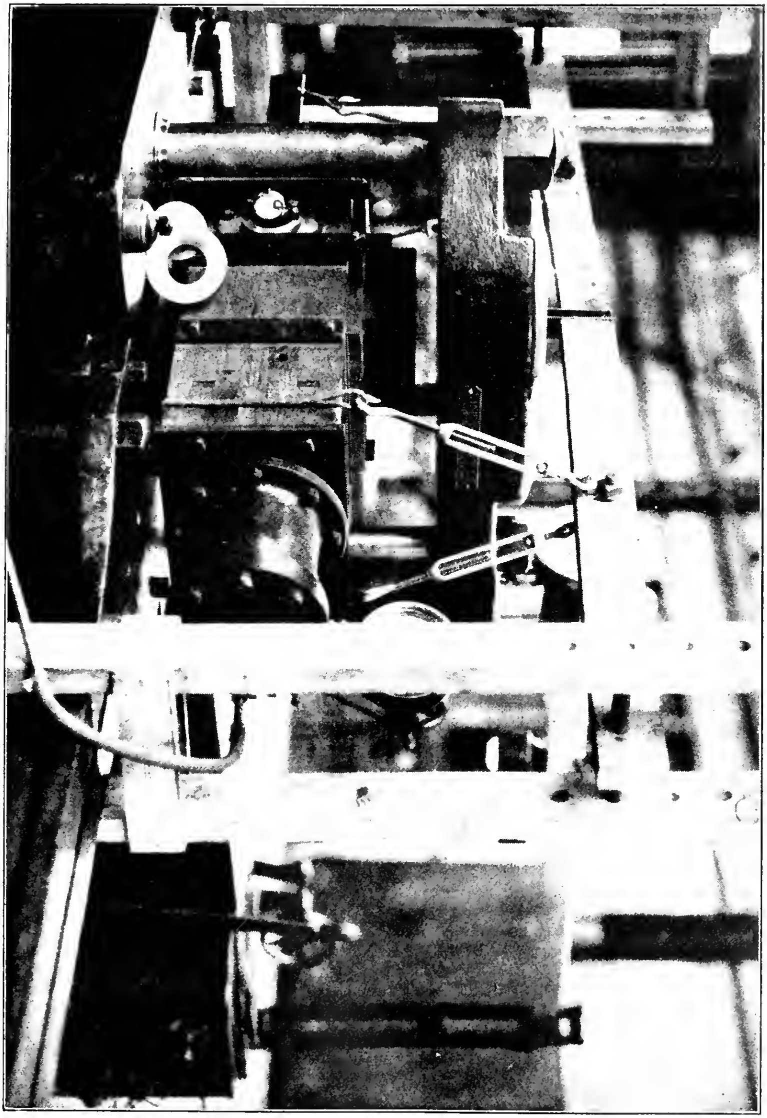


FIG. 4.—APPARATUS FOR MEASURING SURFACE FRICTION BETWEEN PRISMS AND SOILS.

earth in the cylinder, pressure being applied to the earth through the 12-in. piston, as before, with a testing machine. Various working disks and cups have been constructed and tried out in position on the bearing, the disks being fabricated of steel, concrete, and other materials, and the cup-shaped disk having vertical diaphragms to prevent turning of the sample of earth in the cupped portion on account of the resistance of the earth in the cylinder portion. In the use of the apparatus, the purpose is to measure carefully the twisting moment required to cause consecutive infinitesimal rotational displacements of the bearing when the earth is placed under a range of known pressures from the piston and testing machine (see Fig. 2). By varying the height of earth, y (see Fig. 1), some opportunity is afforded for determining the sphere of influence of the shears, etc.

In providing rotary displacements to the disks and ball bearing, a gear and rack movement beneath the base of cylinder is actuated by a piston under oil pressure in a smaller cylinder shown on the side of the main cylinder, Fig. 2. The pressure for this purpose is supplied by a small accumulator connected by piping to the apparatus. (Not shown in Fig. 2.)

In measuring the oil pressure in the small cylinder an Ashcroft pressure gauge (see Fig. 2) was calibrated on an Emery tester for loads greater than 15 lb. per sq. in. Below this value, where the most important phenomena are apparent, this gauge is not sensitive enough for the purpose intended, and the pressure is read directly by a glass tube connected with a mercury reservoir (see Fig. 2). It has been found in the experiments on earths already made that the force required to give a small rotary displacement to the bearing can be read to increments of $\frac{1}{10}$ lb. per sq. in., or on the piston of the auxiliary cylinder to intervals of 3 lb. The mechanism is calibrated for mechanical friction, etc., by superposing weights on the turn-table, up to 1 000 lb., the friction being small, practically constant, and mainly confined to the piston of the small cylinder.

In fabricating this apparatus, the sides of the disks and cupped receptacles were ground to a maximum clearance of about 0.002 in. so as to avoid contact of the surfaces. The disks and cups have 30 sq. in. of surface or 6.18 in. diameter. The radius of the gear is 5 in. and the effective arm of the disk is $\frac{1}{3} \times 6.18 = 2.06$. The equation for calculating the coefficient of friction, f, of the earth is then: effective force on piston $\times$ 5 = effective pressure on disk $\times$ 2.06 $\times$ f, but the apparatus can be disconnected so that the efficiency of each part, piston, rack and gear, or bearing can be found independently as well as for the whole mechanism.

Thus far the tests with this apparatus show a good behavior, the committee, in fact, has obtained results on from 20 to 30 standard sands that are in fair agreement with others.

In general, however, the range of deviation from the mean again shows the need of careful and systematic experimental studies of the influence of each variable before a satisfactory explanation of the phenomena presented can be given and a segregation or elimination of the influence of any particular variable be affected as needed.

One point in the use of the chambered cup receptacle for the earth will perhaps need some explanation in regard to the character of the tangential resistance of the earth on itself or on a body such as the plane disk. Several classes of frictions are common in engineering, among others, earth on steel and concrete, as in sheet- and concrete-piling, or wood, also the resistance of the earth on itself. The French authorities, Boussinesq and Flamant, are of the opinion that, however rough the bodies immersed in the earth may be, the maximum tangential force obtainable will be due to the inherent friction of the earth on itself for the valleys or depressions of the rough surface of the body will be filled by the earth just as in either glacial detrusion or an ordinary lubricant. The partitions of the cups are made sharp at the upper edge, and, taking into account the foregoing remarks, it is believed that the cupped disk will suffice for the purpose, as the earth must roll or slip on itself. A small model, with a glass cylinder and a piston with sharp vertical vanes, allowed the action occurring to be easily visible when the piston was rotated under pressure, and it was in conformity with the foregoing interpretation. In this connection, the committee has read the recent paper by William Cain, M. Am. Soc. C. E.,* and will be very glad to investigate the question of cohesion, as suggested by him. In fact, in a general analysis of earths, such a question obviously cannot be ignored, and all types of equilibrium must be considered.

The apparatus shown by Fig. 4 needs a brief description. It was arranged to study qualitatively the effect of the form factors, etc., of model "piles" when pushed through classified earths under various pressures. At first, smooth oak piles were used, the perimeters being constant and the cross-section varying, as square, triangular, round, etc. Again, the diameters were varied, and so on. These tests are being carried out as preliminary studies on large piles to see whether it is advisable to attempt the work on a larger scale with the high-power testing machines available.

A number of preliminary tests, already placed in the hands of your main committee, show fairly concordant results, with small departures from the mean in the frictional determinations; but, before

* "Cohesion in Earth: The Need for Comprehensive Experimentation to Determine the Coefficients of Cohesion", *Proceedings,* Am. Soc. C. E., for December, 1915.

the more complete tests can be carried out, the gauge problem must be settled. The committee, meanwhile, has had its test pieces for studying the form factors of "piles" duplicated in steel specimens of different perimeters and cross-sections, etc., all polished to the same degree of smoothness, the weight being kept as uniform as possible by using hollow steel sections.

After designing and constructing this apparatus, a careful study of Dr. Wilson's investigation showed that the committee had made use of some of his mechanical principles. For example, an upper and lower piston is used in the box (see Fig. 4) in order that, whatever the effect of friction on the side-walls, its action will be symmetrical with reference to the specimen. To effect this it was necessary to devise a lever system for suspending the casing enclosing the earth and the specimen, so as to insure that the relative motion of each piston with reference to the test specimen will be the same. This lever system is simple, and works satisfactorily. Dr. Wilson used also the principle of counter-balancing, otherwise the two apparatus are quite different and for different classes of experiments.

The sub-committee consists of Dr. G. R. Olshausen, of the Washington Laboratory, Mr. A. V. Bleininger and J. H. Griffith, M. Am. Soc. C. E., of the Pittsburgh Laboratory, the latter being Chairman.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

THE TWELFTH STREET TRAFFICWAY VIADUCT, KANSAS CITY, MISSOURI

Discussion.*

By Messrs. John Lyle Harrington and E. E. Howard.†

Mr. Harrington.

John Lyle Harrington,‡ M. Am. Soc. C. E. (by letter).—So much of the Twelfth Street Trafficway Viaduct is of usual construction, and the author has exposed so fully the elements which are of interest to the engineer who is thoroughly experienced in the design of reinforced-concrete structures, that few matters pertaining to the viaduct require further comment.

Some designers of reinforced-concrete structures consider the work so simple that their plans consist of a few general drawings showing principal dimensions, the number, size, and approximate position of reinforcing bars, and with a few notes pertaining to ties, constituents of concrete, and character of finish; and their specifications consist of little more than references to standard specifications for materials, a brief description of the structure, and the clauses relating to bids. Those of another class, generally of European training, go to the opposite extreme, and make extremely full plans and all the detailed calculations necessary for the exact determination of the stresses in continuously-framed structures, composed of uniformly perfect materials, moulded and placed exactly in accord with the plans. Both are in error. Ill-considered, carelessly-made plans and loosely-drawn specifications are responsible for a large number of defective structures and for many costly failures. Lax supervision is almost sure to follow such designing; and, if the engineer has such

* Discussion of the paper by E. E. Howard, M. Am. Soc. C. E., continued from November, 1915, *Proceedings*.

† Author's closure.

‡ Kansas City, Mo.

Mr. Harrington. small regard for thorough work, the contractor and his foremen and workmen surely cannot be expected to give the construction the greater thought and care essential to satisfactory workmanship.

On the other hand, the extremist who bases his plans on the expectation of perfect materials and workmanship, and allows nothing for imperfections in both, produces designs which, though carried out with all reasonable care, cannot secure satisfactory results. At the same time, he wastes much labor in substantially useless calculation, for considerations of convenience and of uniformity of design do not permit of sectioning exactly in accord with the calculated stresses, and knowledge of the imperfections of materials, of the shortcomings of workmen, and of the difficulties of construction, leads to the making of many assumptions and approximations.

Competent and experienced designers, who know and respect the theories involved in the design, but who also give careful consideration to the imperfections of the materials and the practical difficulties of construction, will secure the satisfactory and enduring structures. Mathematical analysis must be supported by sound judgment.

The advocates of the use of high-carbon steel for reinforcing concrete rarely understand its fragility. Any engineer who has had much experience in the shops knows that even medium steel, when dropped from the skids or otherwise roughly handled, is likely to be fractured; and in many instances which have come to the writer's attention, the breakage of high-carbon steel bars in unloading and handling has been so great as to cause serious doubt as to their quality. The bending of reinforcing bars is not a nice job: It is done in haste, and generally by unskilled workmen, often with unsuitable tools; hence breakage, or what is worse, incipient cracks, which escape notice but enlarge under stress in the structure, is sure to result from the use of this fragile material.

In the writer's opinion, the saving in cost resulting from the use of high-carbon steel does not warrant its adoption. The saving is generally estimated to be proportional to the difference between the unit stresses permissible in the various grades of steel, but this is not true, for, as every experienced designer knows, members cannot be proportioned exactly in accord with the stresses in them, and a large quantity of ties, hoops, and spacers are necessary, regardless of the unit stresses used. The saving is not worth the risk, particularly in structures subject to moving loads.

The finish of concrete structures is one of the most serious moot questions relating to them. In choosing a finish, the improvement in appearance is but one of the considerations; the added cost, the greater absorption of water, and the fouling by smoke resulting from the breaking of the cement skin, must be carefully considered. If the structure is situated so that few will see it at close range, or that it will be blackened by smoke, the expense of treating the surface is not warranted. The writer recently examined a viaduct over a railway yard, and it was covered with soot to such an extent that neither the character of the surface nor the material of the structure could be readily determined. In parks, on boulevards, and in other exposed positions, however, where many view the structure daily, bush-hammering, rubbing, floating, or some other satisfactory method of finishing the surface should be used in order to remove ugly form marks and secure uniformity of color and texture. There should be no attempt to make concrete resemble stone, but flat surfaces should be broken. Plastering is almost certain to scale off and leave a surface uglier than that left by the forms; and, except possibly by using steel-lined forms, it is practically impossible to secure satisfactory surfaces, except by some mechanical treatment. Mr. Harrington.

No amount of surface dressing, however, will compensate for ugly lines and details, and the use of brick, tile, or plaster ornaments is rarely if ever commendable. The designer of such structures as this must rely for appearances chiefly on his ability to give them form and line suitable to the service to be rendered by the structure and in harmony with its dimensions and surroundings. The selection of the central or distinguishing features and the general treatment of the principal forms and parts of the structure are of vastly more importance than ornamentation or finish of surface.

The writer had too large a part in the design and construction of this viaduct to permit him to extol its appearance. The situation and conditions were unusually difficult, hence careful study was required to secure such esthetic results as the general views of the viaduct disclose.

E. E. Howard,* M. Am. Soc. C. E. (by letter).—It is of interest to observe that the mathematical demonstrations of Mr. Mensch and Mr. Slettum alike warrant the conclusion that the approximate methods by which the columns were actually proportioned give results within safe limits. There are refinements beyond which ordinary designing calculations for elastic structures need not be carried, provided there are occasional demonstrations that the approximate methods will vary only within safe limits. The type of arch and abutments suggested by Mr. Mensch has been considered and analyzed for similar cases, although not for this specific one, and the additional material in the arch proper to provide for the greater stresses, the adjustment for foundations, etc., never seemed to be compensated for by the saving in abutments. The foundation difficulty referred to may easily become quite serious. Mr. Howard.

To answer Mr. Mensch regarding high-carbon steel, the writer can suggest only that the same conservatism which leads most engineers

* Kansas City, Mo.

Mr. Howard. to use medium steel in structures wholly of steel, would prompt the use of the same material in structures partly of steel. The writer has seen high-carbon steel bars, actually by the carload, which had been inspected and accepted at the mill, broken by merely being thrown from the car in unloading. Evidently, the sentence concerning the fastening of bars was not wholly clear, for the bars were tied together principally to hold them in correct position while placing the concrete. Any joining of bars intended to transmit the load from one bar to another was made by some definite splice, such, for instance, as bolted rope clips.

Mr. Holmes' suggestions for constructing influence lines for extreme fiber stress brings forward another of the frequent cases in which individual preference may enter. In this special instance, the designers felt that to carry out the equations another step and plat the influence in lines of extreme fibers would require more work than the method followed. It is easy to agree with Mr. Holmes that in certain cases the other method would be most desirable.

The writer is most heartily in accord with Mr. Holmes' views concerning the relations between engineers, contractors, and public officials. The absurd and ridiculous laws sometimes controlling public construction have been cause for exasperation to many engineers, although, after all, the rabbit-like timidity of public officials, in fearing to do what they believe to be right, may be equally at fault. Although supposedly representing a whole community, public officials are often prone to listen to the vociferous requirement and the threats or promises of a small group of those who have personal interests to promote, and to forget the great silent majority who are not present. Fortunately, there are occasional very refreshing exceptions.

Mr. Upson's figures concerning the piles are substantially correct, but, as a just concession to the increased percentage of overhead cost due to the reduced quantities, a payment of \$2 462 was made to the Contractor. This still left the City about \$20 000 ahead of the probable cost of pre-cast piles. The Raymond piles were well suited to the foundation conditions and to the season in which the work had to be done.

The rather unusual requirements of a cement-gun finish, referred to by Mr. Ash, were included as one alternative method of surface finish only after the manufacturers of the cement-gun equipment gave assurances that they could provide such work, and gave an approximate price for it. The experiences of other users of the cement gun, especially on viaducts of the Kansas City Terminal Company, cast serious doubt on the practicability of producing an even, uniform, $\frac{1}{8}$-in. mortar coat over irregular surfaces. It was evident that the extruding corners would not be coated at all, that re-entrant corners and moulds would be filled and rounded, and that the clean lines of the structure would be lost. It is the writer's opinion that the cheap and satisfactory surface finish for ordinary concrete will some day be supplied by some kind of lime-cement wash or paint which can be brushed on, which will have characteristics so similar to the concrete that it will not flake off. Many industrial chemists are studying cements, limes, and mortars, and such a wash should be available at no distant day. Mr. Howard.

In conclusion, it has been a pleasure to the writer on frequent occasions to hear expressions of pride and satisfaction, from residents of Kansas City, who provided the money for the viaduct, in the pleasing appearance and evident excellency of construction. The public verdict is that the structure is a success. The old excuse that engineers have been prone to bring forward, that their principals would not provide money for beautiful structures and therefore such structures were ugly, belonged to pioneer conditions, and, as Mr. Green suggests, the United States may fairly be said to have passed that stage. It would be hard to find any one, even of those who paid special assessments for this viaduct, who would ask the return of the small additional percentage which it cost, over the expense of a series of posts and beams which would have carried the load. If the Engineering Profession will lead the way for substantial and beautiful bridges, public sentiment will follow fast enough.

The writer desires to express his cordial appreciation for the courteous words of approval of his paper by those who discussed it; and, on behalf of all the engineers connected with the design and construction of the Twelfth Street Trafficway Viaduct, for their compliments in regard to the structure.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

THE AUTOMATIC VOLUMETER

Discussion.*

By E. G. Hopson, M. Am. Soc. C. E.†

E. G. Hopson,‡ M. Am. Soc. C. E. (by letter).—Mr. Booth suggests the possible usefulness of the automatic volumeter for metering individual fire mains supplying sprinkler systems, and it would seem that this proposition might have considerable merit. Mr. Hopson.

With regard to these fire mains the conditions, as understood by the writer, are as follows: Such mains are intended for use solely for fire protection, and, ordinarily, are merely filled with water under pressure which is not drawn upon, save possibly for occasional flushing or test. The quantity of water used strictly for fire purposes is negligible, under ordinary conditions, where no fires occur, and, even when they do, it is relatively small as compared with the daily use of water for domestic or mercantile purposes. There is no object in measuring the water used strictly for fire purposes, because its quantity is insignificant at all times, and the idea of economy or limitation in its use is not to be considered.

The illicit use of water from these fire mains has always been a standing annoyance, and has led to the requirement referred to by Mr. Booth that these services be metered. That, again, introduces another difficulty, as a meter for a 4-in. or 6-in. main is not only expensive, but is not suited for the detection and registration of illicit drafts, which, though small in each case, are considerable in the aggregate, owing to their frequency. In practice, this difficulty has been met, in part by the introduction of a small metered by-pass which permits the complete registration of all such uses, but has the dis-

* Discussion on the paper by E. G. Hopson, M. Am. Soc. C. E., continued from December, 1915, *Proceedings*.

† Author's closure.

‡ Portland, Ore.

Mr. Hopson. advantage that the main supply is necessarily cut off, and dependence must be placed on some automatic process of throwing in the main during an emergency. From the fire protection standpoint, a system dependent on any automatic control has decidedly objectionable features.

As Mr. Booth correctly points out, if the volumeter can only operate under a velocity head of 0.001 ft. and upward, considerable quantities of unregistered water might pass through a 4 or 6-in. main, if dependence was placed on the apparatus. This estimate is that as much as 22 gal. per min. on a 6-in. pipe, or 10 gal. per min. on a 4-in. pipe might go undetected.

The exact head necessary to start the volumeter recording is not known, no special test having been made for that purpose. The writer has found, however, that it will start and stop under changes of head as small as 0.001 ft. This is a very small head, and perhaps it will be well to assume for present purposes that it is the limit of accuracy. Such a head corresponds to a velocity of about 3 in. per sec. If the fire main can be made to discharge through a reduced cross-section so that this velocity will correspond to a relatively small discharge, then measurement by the volumeter, taken at the contracted section, may be possible and may be sufficient for the purpose in view.

It is suggested, therefore, that a reducer be inserted in the main, possibly in the manner indicated in Fig. 10. This shows a 4-in. main reduced to a $1\frac{1}{2}$-in. throat in about 1 ft. of distance and then correspondingly expanded to the original diameter. The reduced area of cross-section is about one-seventh of the full section, and the velocity at the throat is seven times that in the main. Assuming a working velocity of 6 ft. in the fire main, or a discharge of 230 gal. per min., there would be a loss of head (due to the reducer) of only about $3\frac{1}{2}$ ft. or about 1 lb. pressure. Thus, for all practical purposes of fire protection, the fire main would be unthrottled and wholly free from objectionable automatic control.

The volumeter could be connected with the reducer by the influent pipe, *a*, and the effluent, *b*, similar in manner to the connection of the registering apparatus of a Venturi meter. It might equally well be connected by a Pitot tube at the throat as at a' and a piezometric connection at b' below the reducer, for the effluent. Such an apparatus, in a 4-in. main, would detect and register uses of water as small as 1.4 gal. per min.; or in a 6-in. main, a little more than double that quantity.

Though this minimum might still exclude very small drafts, or even small constant leaks, it would show clearly all the ordinary drafts likely to be made in a mercantile establishment, such as the drawing of a pail of water, the use of a hose, or similar details.

The limitation of the apparatus with reference to minimum measurement is governed by the maximum practical velocity at the throat.

This has been assumed at 40 ft., or perhaps a little more, which apparently is possible without any sensible sacrifice of working pressure in the fire main. If, on the other hand, there is an ample sufficiency of pressure in the fire main, so that as much as 20 lb. pressure can be sacrificed at the reducer, it might then be possible to contract the diameter of the throat still more, and thus correspondingly increase velocities and secure a measurement of flow as low as about $\frac{3}{4}$ gal. per min. on a 4-in. main. Mr. Hopson.

An advantage of such an arrangement is that it is good from the fire-protection standpoint, and the cost should be very small. The 25-in. reducer would be cheap, and the volumeter and connections should cost only a few dollars. The apparatus has no working parts, and will not get out of order by disuse, but it would be necessary to protect it from frost.

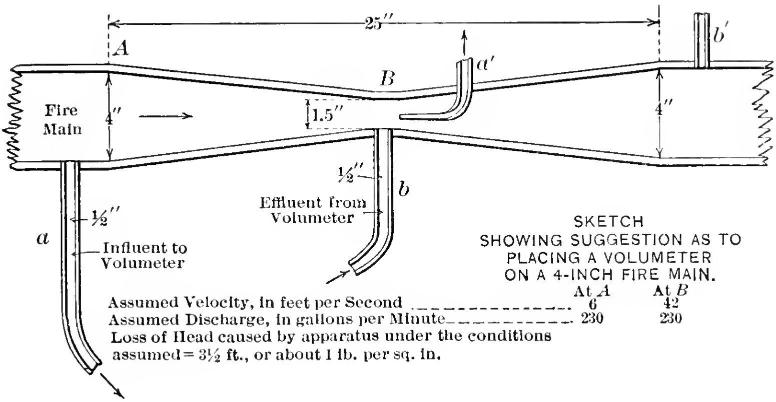


FIG. 10.

One objection to such an arrangement, called to the writer's attention by Mr. Booth, is the fact that the contracted section of the main has already been objected to by underwriters in the case of the Venturi meter, because of the fear that foreign matter, such as a block, or a stone, or other article, unwittingly left in the pipe when it was laid, might become lodged in the throat and entirely block the system. This objection, the writer believes, has met with considerable support, but for reasons that do not appear to be well founded. If there is any real danger to be feared on this score, it can be absolutely removed by the introduction of a coarse screen in the main above the contraction. Such a screen, having a mesh of heavy wire, or rods, say, at 1-in. intervals, would prevent any article large enough to block the throat from reaching it, and would hold it at a point where its blocking effect on the main would be inappreciable and where it could be removed.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

SUGGESTED CHANGES AND EXTENSIONS OF THE UNITED STATES WEATHER BUREAU SERVICE IN CALIFORNIA

REPORT OF A COMMITTEE OF THE SOUTHERN CALIFORNIA ASSOCIATION OF MEMBERS.

Discussion.*

BY FRED. H. TIBBETTS, ASSOC. M. AM. SOC. C. E.

FRED. H. TIBBETTS,† Assoc. M. Am. Soc. C. E. (by letter).—The writer is particularly pleased with the constructive criticism contained in this report, and in the subsequent discussions. There is a strong and rapidly growing sentiment favoring the participation by organized engineers in the discussion of public problems. Engineers are the chief users of the data gathered by the Weather Bureau, and hence should be particularly qualified to support it and to urge the extension by Congress of its exceedingly useful work. Mr. Tibbetts.

Among the many important matters listed by the authors as pertaining to the Weather Bureau, the writer wishes to discuss the relation of the work of that Bureau to flood control and drainage problems, particularly in the Central Valley of California.

In the Sacramento Valley many important cities and towns, including the State Capital, as well as large areas of rich farming land, lie below the flood-plain of the river, and are partly protected by incomplete flood-control and drainage works. The accurate prediction of floods is a matter of the greatest importance. Every general flood has been attended by losses running from small amounts up to sums exceeding $5 000 000. The Weather Bureau deserves the greatest credit for predicting all the important floods, and for the prompt collection of the data issued in the daily river bulletins during the flood season,

* Discussion of the paper by George S. Binckley, M. Am. Soc. C. E., and Charles H. Lee, Assoc. M. Am. Soc. C. E., continued from August, 1915, *Proceedings*.

† San Francisco, Cal.

Mr. Tibbetts. as well as for the uniform courtesy and devotion of its staff. Under the present organization, and with the limited funds available, however, it is impossible to predict gauge heights with any great degree of accuracy, or more than 1 or 2 days in advance.

The typical winter storms of California are areas of low pressure which become detached from the much larger area which remains more or less permanently in the vicinity of the Aleutian Islands. These detached areas are swept eastward over the North Pacific Ocean, by the prevailing eastward drift of the atmosphere, until they impinge on the western shore of the continent. Their progress eastward is then determined by the direction from which they have advanced, and largely by local conditions. The storms are frequently broken up, or the direction of their movement is changed, by the high mountain ranges. The location of high-pressure areas at the time the storms strike the Coast is also important. A high-pressure area over Western Canada tends to deflect a storm southward; such an area over Central or Southern California tends to hold it to the north, and make it move parallel to the Canadian boundary. In general, these storms cannot be predicted on the Pacific Coast until they have actually arrived, and as they move ordinarily at a rate of from 10 to 15 miles per hour, storm warnings are too late to be of much value. Disastrous floods in a big river system such as the Sacramento occur only as the accumulative result of a number of such storms occurring in such quick succession that heavy precipitation continues for a number of days or weeks. If, when a heavy rainfall is occurring in the Sacramento Valley it was possible to know that there was, or was not, one, two, or more other storms a day or two off the coast, it would then be possible to predict with much greater accuracy, and for a much longer period in advance, the heavy and continued precipitation which causes high and prolonged flood stages in the river. For such work, two or three, or even one, station in the ocean from 500 to 1 000 miles off the western coast, would seem to the writer to be of as much value as all the other stations in California taken together. Such stations, if established in the ocean, would be not unlike some of the lightships off the coast. Only a limited outlay, and a limited number of observers would be necessary. The stations, of course, should be equipped with wireless, so that storms moving over the ocean could be reported immediately as to intensity, direction, and rate of movement. It is probable that, if regular reports were received from all ships equipped with wireless moving in the North Pacific, many of the severe storms could be accurately foretold a number of days before they arrived. One of the authors has suggested to the writer the occasional special use of naval vessels. The lines of ocean travel from Puget Sound to the Orient appear to go far enough north to make such observations of value.

Mr. Tibbetts.

The establishment of additional Weather Bureau Stations in the higher altitudes, as recommended by the authors, would also be of much use in predicting floods. The importance of the temperature of the air, particularly in the mountains, is almost equal to that of the precipitation. During the maximum discharge of the larger rivers, all but a negligible proportion of the water comes from the higher altitudes, the proportion probably being not unlike that of the annual run-off. Very few of the Weather Bureau Stations are high enough to indicate the conditions which give high rates of run-off. The fortunate fact that the Southern Pacific crosses the mountains at comparatively high altitudes, and is giving constant and valuable support to the Weather Bureau, is of great assistance. The effect of high temperatures in producing high rates of run-off has not received from engineers the study which it deserves, and to this can be largely attributed some of the apparently erratic results of the very wet January of 1916. During the heavy storms of that month the river at no time reached a dangerous stage, probably because the temperature in the mountains was so low that the precipitation piled up in temporary storage as snow. The highest stage of the river reached thus far in 1916, accompanied by a prolonged, heavy run-off (although at no time dangerous), occurred in response to comparatively light precipitation, accompanied by unusually warm weather during the first half of February.

Colusa Basin comprises the northeast corner of the flood basin of the Sacramento River. Back of the Reclamation Districts, which include more than 120 000 acres, there is a water-shed of about 1 600 sq. miles. About 950 sq. miles of this are occupied by comparatively level valleys and plains, and the remainder, producing most of the run-off, is composed of the bare foot-hills of the Coast Range rising to elevations of from 1 500 to 2 000 ft. The flood-control works now under construction are designed primarily to handle the run-off from these hills at a maximum rate of perhaps 25 000 sec-ft. There are only four (all co-operative) stations in this drainage area, all of which are below 200 ft. elevation. Rainfall records at these stations do not necessarily give an index of the run-off. The first flood of 1916, from January 3d to 8th, aggregating about 110 000 acre-ft., was accompanied by an unusually violent storm, averaging in the valley nearly 4 in. of precipitation in less than 24 hours. This indicated satisfactorily the crest of this flood 4 or 5 days in advance. The next and larger flood occurred between January 24th and 28th, and was not accompanied by any unusual precipitation of record at the stations in the water-shed mentioned previously. Had the stations been at the elevations at which the precipitation occurred, which caused this flood, they would probably have indicated its size and time of occurrence. This is inferred from the fact that this storm is shown clearly by the

Mr. Tibbetts. rainfall records at Kennett, which although 120 miles farther north, and on quite a different water-shed, is at an elevation of 730 ft. The writer concludes that the vertical distribution of rainfall stations is far more important, from the standpoint of flood control, than their geographical location.

The work of the Weather Bureau in collecting and making public with amazing promptness the actual conditions all along the river, is of the greatest value. By 9 A. M. it is possible to ascertain, by telephoning to the Weather Bureau, the precipitation at each station for the preceding 24 hours, the stage of the river at 7 o'clock that morning, and its rise or fall within the last 24 hours. The mail service is so prompt that these records are usually received through the mail on the day that they are issued. The writer has only one suggestion here, and that is that more frequent observations during critical periods, or, better still, the use of automatic instruments giving a continuous record of the river stage, would be of the utmost interest and value. For example, at Red Bluff, at the head of the Sacramento Valley, the river sometimes rises or falls 15 ft. or more in 24 hours. The variation is almost as great at Colusa, near the head of the heavy flood-control works. The highest gauge at Colusa is ordinarily within from 1 to 3 ft. of that at Red Bluff, and from 18 to 36 hours later. Daily readings at Red Bluff may miss the crest of the flood by a number of feet, and render it that much more difficult to predict accurately the stage of water which will be reached on the levees from Stony Creek to the Feather River.

The writer's conclusions with regard to the work of the Weather Bureau, as it affects flood control and drainage, are:

Two observation stations in the ocean would be of more value in predicting several days in advance the occurrence of heavy storms than all the present stations in California combined. Regular information from vessels in the ocean might be of much assistance.

A more uniform vertical distribution of the Weather Bureau Stations, particularly in the higher altitudes, is desirable.

More importance and more study should be given by engineers to the effect of temperature in the mountains on the maximum rate of run-off.

The Weather Bureau has developed amazing efficiency and promptness in the collection and publication of river bulletins, and its local officials are uniformly courteous and desirous of making their work of the utmost usefulness, but the prediction of continued storms, and prolonged high-water stages, for a sufficient length of time to be of much use in flood-control work is physically impossible under present conditions on the Pacific Coast. The timely warnings issued, however, have been of inestimable value in saving life and property.

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PAPERS AND DISCUSSIONS

A STUDY OF THE DEPTH OF ANNUAL EVAPORATION FROM LAKE CONCHOS, MEXICO

Discussion.*

By Charles W. Comstock, M. Am. Soc. C. E.

Charles W. Comstock,† M. Am. Soc. C. E. (by letter).—The authors have contributed to the general fund of information on evaporation the results of 5 months' observations on two land pans and one floating pan, and about 1 month's observations on a second floating pan at Lake Conchos. Had they restricted themselves to legitimate conclusions from these observations, there would have been little to discuss except, perhaps, by those familiar with conditions in the vicinity of La Boquilla. They have gone into the field of speculation, however, and have built an unstable structure of generalizations on a very insecure foundation, *viz.*, one of the many Bigelow formulas. By this process, they have raised a doubt as to the validity of any of their conclusions. Mr. Comstock.

Their criterion of correctness is apparent agreement with the Bigelow formula; therefore, discussion of that formula will not be out of place. Professor Bigelow has put forward a number of general formulas to connect evaporation with other meteorological conditions. The one used by the authors is that published in the *Monthly Weather Review*, for February, 1910.

Professor Bigelow's fundamental idea was that an evaporation formula containing, as a factor, the difference between the vapor tension of saturation at the temperature of the water surface and that at the dew point of the air, cannot be satisfactory because it does not agree in form with the rational formula derived by the integration of the differential equation for diffusion in one dimension in a quiet

* Discussion of the paper by Edwin Duryea, Jr., M. Am. Soc. C. E., and H. L. Haehl, Assoc. M. Am. Soc. C. E., continued from February, 1916, *Proceedings*.

† Denver, Colo.

Mr. Comstock.

atmosphere. As a matter of fact, we know that diffusion in a quiet atmosphere can take place only under the most carefully arranged and controlled laboratory conditions, and never in any outdoor surroundings. However, he adopted a form in which the ratio of vapor tensions, instead of their difference, is the controlling factor. There are many objections to this. As the vapor tension at the dew point enters in the denominator of the fraction, the rate of evaporation into perfectly dry air would be infinite. The absurdity of this is apparent. It is true that perfectly dry air is not found in Nature, but such a condition could be easily provided in the laboratory. Professor Bigelow, thus far, has totally ignored this consequence. Again, even if the air became saturated, evaporation would not cease, according to the Bigelow formula, as no factor therein becomes zero. Professor Bigelow, in commenting* on this feature, says:

"It is, however, probable that even when $e_s = e_d$, and the vapor pressure in the air is the same as that at the water surface, there is a flow of vapor in the tubes required to maintain the vapor pressure e_d near the water."

This explains nothing. If the air is saturated, there is no room for more water vapor. If the saturated air is partly or wholly removed by the wind, and its place is taken by unsaturated air, the flow of vapor from the water surface can go on. This, no doubt, is what Professor Bigelow had in mind, but it does not cover the assumed case of equal vapor pressures in the air and at the water surface. By his formula, water must go on evaporating in a closed chamber filled with saturated air, though it is not apparent what is to become of the vapor.

There is a still more important inconsistency in Professor Bigelow's argument. He rejects the idea that rate of evaporation depends on difference of vapor tensions at water temperature and dew-point temperature, but he determines the vapor tension at the dew point by the use of the psychrometer, notwithstanding that the psychrometric tables are calculated from a formula derived by consideration of the very relation which he discards.† If this relation is not true, the psychrometric tables do not give the temperature or vapor tension at the dew point, and the constancy of coefficients, on which Professor Bigelow relies to prove the correctness of his formula, is entirely misleading.

The authors' Subsidiary Conclusions (*a*), (*b*), and (*c*) are those of Professor Bigelow, and, in fact, are based on mere repetition of his figures and argument. Although it is not believed to be important, it is not clear why the authors should persist in squaring Professor Bigelow's round pans. The writer has been unable to find

* *Monthly Weather Review*, 1908, p. 439.

† Hann, "Lehrbuch der Meteorologie," Second Edition, 1906, p. 164.

Mr. Comstock.

anything in any account of the Salton Sea campaign, or of the preliminary campaign at Reno, which justifies the assumption of square pans, and the use of round pans at Reno is clearly shown by the half-tone engravings.*

Subsidiary Conclusion (*a*) deals with relative depths of evaporation from pans of different sizes. Here the authors quote the values of the coefficient in the Bigelow formula, as given in "Abstract of Data, No. 4," issued by the United States Weather Bureau.† Professor Bigelow gives somewhat different values for this coefficient.‡ They are compared in Table 67.

TABLE 67.

Diameter of pan, in feet.	Coefficient in Bigelow Formula:	
	"Abstract of Data, No. 4."	*Monthly Weather Review.*
2	0.042	0.040
3	.....	0.042
4	0.036	0.037
6	0.031	0.029
12	....	0.025
Lake surface.	0.023 to 0.025	.....

Whichever set is accepted, the values of the coefficient are regarded as measuring the relative depths of evaporation from pans of the corresponding diameters. Professor Bigelow states:‡

"The evidence is decisive, * * * that water evaporates much faster from small pans than from large pans. This is because the wind action tends to clear a small pan of vapor, making over it a dryer mixture, than it does a large pan or water surface, where vapor is merely transported from one side of the water area to the other side of it. Especially, over a lake or reservoir the vapor is carried along from point to point without drying the mixture of vapor and air resting on the water surface."

If it is admitted as a fact that water has been observed to evaporate faster from small pans than from large ones, it is too great a tax on our credulity to accept the explanation here offered as accounting for differences between pans 2, 3, and 4 ft. in diameter. That any atmospheric movement which can be called wind would clear water vapor from a 2-ft. pan more quickly or more completely than from one 3 or 4 ft. in diameter, is inconceivable.

* Fig. 3 on p. 25, and Figs. 5*a*, 5*b*, 5*c*, and 5*d*, on p. 27, *Monthly Weather Review*, February, 1908.

† Published subsequently in *Engineering News*, Vol. 63.

‡ *Monthly Weather Review*, July, 1910, p. 1133.

Mr. Comstock.

Professor Bigelow says,* further:

"In order to test the ratio of evaporation from pans of different sizes, our records include the following combinations: (1) A 4-foot pan self-registered hourly and a 2-foot pan alongside on the ground near Tower No. 1; (2) a row of 3 pans, 2-foot, 4-foot, 6-foot in diameter, on a platform on Tower No. 3, about half a mile from shore, and as near the water as was practicable; (3) a row of 4 pans, 2-foot, 4-foot, 6-foot, 12-foot, on a series of adjoining rafts floating in the Salt Creek slue in calm water. The ratios are quite steady and the results have been incorporated into the final value of the coefficient."

For the first two of the combinations here described, he does not give the detailed results of the observations or the coefficients calculated for the different pans. For the third combination, he gives the following values of the coefficient:

2-ft. pan	0.031
4- " "	0.030
6- " "	0.026
12- " "	0.025

The observations at Indio, in 1907, by Dr. C. Abbe, Jr., showed very clearly that the greater depths of evaporation from the smaller than from the larger pans in that instance were due to higher temperatures of the water in the smaller pans. Such temperature differences are to be expected in land pans, but cannot exist in floating pans. The Indio observations certainly contain nothing to support the hypothesis that the size of the pan *per se* has any influence on the depth of evaporation under otherwise identical conditions, or to justify the remarkable suggestion that such observed differences are to be accounted for by the action of the wind in clearing away the vapor more quickly from a 2-ft. than from a 4-ft. pan.

The ease with which Professor Bigelow reaches "final conclusions" and the readiness and frequency with which he changes them, are illustrated by comparing his statement of "decisive evidence" in July, 1910, with his equally dogmatic assertion of 1908: "The size of the pans makes an insignificant difference in the amount of evaporation, when they are under identical local conditions."†

This was written after the completion of the Reno campaign and the analysis of its results.

In the absence of more information than has been vouchsafed thus far, the writer may perhaps be pardoned if he fails to see the "decisive" evidence relative to the influence of size of pan.

Subsidiary Conclusion (*b*) has to do with relative evaporation depths from land pans and floating pans. The discussion of this subject by the authors is complicated by their use of the assumed ratios

* *Monthly Weather Review*, July, 1910, p. 1134.

† *Ibid*, February, 1908, p. 38.

for pans of different sizes under identical conditions. It seems certain that water will evaporate more rapidly from land pans than from floating pans under otherwise similar conditions, because the vapor tension at the dew point will be lower over the land pans and because, as a rule, the temperature of the water in land pans will be higher, especially during the day, than in floating pans. Whether the authors' ratio of 80% is justified, however, is another question. Their observations at Laguna Seca seem to support this conclusion, but their work at Lake Conchos leads to a ratio approximating 85%, as do also the Granite Reef observations. The Salton Sea figures and those obtained at California, Ohio, should be rejected because they involve the at least uncertain ratios assumed to exist between evaporation depths from pans of different diameters. If the results at Coyote, Granite Reef, and Lake Conchos (5 months) are combined, the mean is found to be 83.4%, and this seems to the writer more nearly justified than the 80% adopted by the authors. If the separate ratios are weighted by the lengths of periods of observation, the mean will be about 82 per cent. Mr. Comstock.

With respect to Subsidiary Conclusion (*c*), the authors have again followed Professor Bigelow, and their conclusion seems to be based rather on his dicta than on any numerical data. The quotation credited to Professor Bigelow, beginning on page 1745,* is from the report of the Conference Board appointed to outline the Salton Sea campaign, and was signed by Professor Bigelow, Mr. G. K. Gilbert, of the United States Geological Survey, and C. E. Grunsky, M. Am. Soc. C. E. It was written in advance of any work at Salton Sea or at Reno, and was purely speculative. Even as an hypothesis, it is so far at variance with well-known facts as to warrant its summary rejection. The quotation is in part as follows:

"As the air moves across a reservoir and gradually becomes charged with moisture, its rate of absorption diminishes, and the average rate of evaporation for a broad surface is therefore less than for small surfaces."

Does any one think of wind as a mass of air, maintaining its form and the identity of its particles, moving like a rigid body horizontally across a water surface for 10 or 15 miles, and absorbing moisture as it goes? The most casual observation of a floating flag, a column of smoke, or the falling snow shows how far such a concept is removed from the fact. The air particles move with velocities which change rapidly, even abruptly, in magnitude and direction, not only with the position of the point of observation, but also at any chosen point. The motions have vertical components, frequently of high velocity. The atmosphere is cut in all directions by surfaces of discontinuity, and the whole swirling, tumultuous mass is so thoroughly mixed that

* *Proceedings*, Am. Soc. C. E., for September, 1915.

Mr. Comstock. it is impossible to imagine the existence for more than a few minutes at a time of a stratum differing materially in its content of water vapor or in any other respect from the average of the whole.

Nor does the wind velocity, as observed by an ordinary anemometer of the type used by the United States Weather Bureau, give any measure of this mixing effect. These anemometers are affected only by the horizontal component of motion, and they add such components numerically, irrespective of direction. Furthermore, they are arranged so as to record the passage of each mile (or each kilometer) of wind, regardless of whether the motion is uniform for the entire time, or fitful and variable in the extreme.

The most graphic description of the condition which the writer is here attempting to depict is the following by the late Professor S. P. Langley:*

"A prominent feature * * * is that the higher the absolute velocity of the wind, the greater the relative fluctuations which occur in it. In a high wind the air moves in a tumultuous mass, the velocity being at one moment perhaps 40 miles an hour, then diminishing to an almost instantaneous calm, and then resuming.

"The fact that an absolute local calm can momentarily occur during the prevalence of a high wind, was vividly impressed upon me during the observations of February 4, when chancing to look up to the light anemometer, which was revolving so rapidly that the cups were not separately distinguishable, I saw them completely stop for an instant, and then resume their previous high speed of rotation, the whole within the fraction of a second.

* * * * * * *

"* * * The velocity, which was, at the beginning of the interval considered, nearly 23 miles an hour, fell during the course of the first mile to a little over 20 miles an hour. This is the ordinary anemometric record of the wind at such elevations as this (47 metres) above the earth's surface, where it is free from the immediate vicinity of disturbing irregularities, and where it is popularly supposed to move with occasional variation in direction, as the weather-cock indeed indicates, but with such nearly uniform movement that its rate of advance is, during any such brief time as two or three minutes, under ordinary circumstances, approximately uniform. This then may be called the 'wind,' that is, the conventional 'wind' of treatises upon aërodynamics, where its aspect as a practically continuous flow is alone considered. When, however, we turn to the record made with the specially light anemometer, at every second, of this same wind, we find an entirely different state of things. The wind starting with the velocity of 23 miles an hour, at 12 hrs. 10 mins. 18 secs., rose within 10 seconds to a velocity of 33 miles an hour, and within 10 seconds more fell to its initial speed. It then rose within 30 seconds to a velocity of 36 miles an hour, and so on, with alternate risings and fallings, at one time actually stopping; and, as the reader may

* "The Internal Work of the Wind," 1893, pp. 9 *et seq.*

easily observe, passing through 18 notable maxima and as many notable minima, the average interval from a maximum to a minimum being a little over 10 seconds, and the average change of velocity in this time being about 10 miles an hour. Mr. Comstock.

* * * * * * *

"In order to insure clearness of perception, the reader will bear in mind that the diagram does not represent the velocities which obtained coincidentally, along the length of two miles of wind represented, nor the changes in velocity experienced by a single moving particle during the given interval, but that it is a picture of the velocities which were in this wind at the successive instants of its passing the fixed anemometer, which velocities, indeed, were probably nearly the same for a few seconds before and after registry, but which incessantly passed into, and were replaced by others, in a continuous flow of change. But although the observations do not show the actual changes of velocity which any given particle experiences in any assigned interval, these fluctuations cannot be materially different in character from those which are observed at a fixed point, and are shown in the diagram. It may perhaps still further aid us in fixing our ideas, to consider two material particles as starting at the same time over this two-mile course: the one moving with the uniform velocity of 22.6 miles an hour (33 feet per second), which is the average velocity of this wind as observed for the interval between 12 hrs. 10 mins. 18 secs., and 12 hrs. 15 mins. 45 secs., on February 4; the other, during the same interval, having the continuously changing velocities actually indicated by the light anemometer * * *. Their positions at any time may, if desired, be conveniently represented in a diagram, where the abscissa of any point represents the elapsed time in seconds, and the ordinates show the distance, in feet, of the material particle from the starting-point. The path of the first particle will thus be represented by a straight line, while the path of the second particle will be an irregularly curved line, at one time above, and at another time below, the mean straight line just described, but terminating in coincidence with it at the end of the interval. If, now, all the particles in the two miles of wind were simultaneously accelerated and retarded in the same way as this second particle, that is, if the wind were an inelastic fluid, and moved like a solid cylinder, the velocities recorded by the anemometer would be identical with those that obtained along the whole region specified. But the actual circumstances must evidently be far different from this, since the air is an elastic and nearly perfect fluid, subject to condensation and rarefaction. Hence the successive velocities of any given particle (which are in reality the result of incessant changes in all directions), must be conceived as evanescent, taking on something like the sequence recorded by these curves, a very brief time before this air reached the anemometer, and losing it as soon after."

In such wind, as distinguished from the wind of popular imagination, Professor Bigelow's "vapor blanket" must needs have the tenacity and water-proofing qualities of the best rubber in order to remain intact and afford the protection with which it has been credited.

Mr. Comstock.

The authors quote from Professor Bigelow as follows:

"* * * in the arid regions of the West it seems probable that a lake or reservoir evaporates about five-eighths as fast as an isolated pan placed outside the vapor blanket; in other words, this vapor blanket seems to conserve about three-eighths of the water that would otherwise be lost by the evaporation."*

Let us see on what evidence the existence of this "vapor blanket" rests, and what justification there is for the statement that it conserves three-eighths of the water which would otherwise be lost.

At the end of the Reno campaign, Professor Bigelow worked up his results in great detail on the basis of a formula, which he afterward discarded, and with certain assumptions in respect to which he has since changed his mind—notably the influence of size of pan. Having computed the values of the coefficient in his assumed formula for pans exposed at different heights above the surface of the ground, he then "adjusted" them by a perfectly arbitrary process, without a shadow of rational justification, and thus arrived at a limiting value, of which he says:

"The maximum value of C is 0.0430, *which corresponds to a maximum evaporation outside the vapor blanket covering the reservoir,* and it is at some asymptotic distance."

The italics are Professor Bigelow's. The ratios of the values of C at the water surface to this asymptotic value vary from 0.395 to 0.72 for the different towers, and on this evidence is based the statement that the "vapor blanket" conserves three-eighths of the water which would otherwise evaporate.

The reasoning is illogical, and the whole process is unscientific and arbitrary. The only conclusion which can properly be drawn from Professor Bigelow's involved calculations is that water evaporates less rapidly near the ground than it does at some place where the wind velocity is greater and the vapor pressure in the air less, and this was common knowledge before the inauguration of the Reno campaign.

Again, the authors quote from "Abstract of Data, No. 4" as follows:

"These data indicate a nearly uniform rate of evaporation over the area of the water, beginning a short distance from the shore."

The data referred to are observations at two points, 7 000 ft. apart, the most distant less than 1½ miles from shore. The Salton Sea was 45 miles long, from 10 to 15 miles wide, and covered an area of 440 sq. miles. What kind of logic is this? If we are to leap such enormous gaps from a few observations to a broad generalization, almost anything may be proved inductively.

* *Monthly Weather Review,* February, 1908, p. 39.

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It is practically certain that conditions affecting evaporation are not uniform over an area of 440 sq. miles, at least for any length of time. If they are not, the measured evaporations and the coefficients calculated from them would differ from point to point, and Professor Bigelow's accepted ratio of evaporation from a large water surface to that from a floating pan is left without any foundation.

Compare the minute and detailed measurements and calculations which were carried out in the evaporation observations at Reno and Salton Sea, with the off-hand way in which other data are assumed. For example:*

"The automatic record indicates that the sea has fallen about 4.60 ft. annually, or, allowing for the inflow, we have a little more or less than 6.0 ft. by evaporation. It is probable that the inflow from the New and Alamo rivers, together with the precipitation flowing in from the surrounding country amounts to something like 1.5 ft."

And again, from the same source:

"If 70 ins. is admitted as the amount evaporated from the Salton Sea, there remains 38 ins. as the difference between the water in the sea and that in the lower swinging pan."

What is the basis for the assumed inflow? The only channels bringing water to the sea, on which any attempt at measurement has been made, are the Alamo and New Rivers. Gauging stations were established on these streams on June 24th, 1909. The station on the Alamo was discontinued on January 6th, 1912. Concerning that station, the description is, in part:†

"Conditions for obtaining accurate discharge data are poor. The channel is constantly scouring or filling as the stage fluctuates."

In respect to the New River station, the report is even less favorable.‡

"Conditions for obtaining accurate discharge data are exceedingly poor. The great amount of fine silt carried by this stream causes continual changes in the channel. The current is light at low stages. Floods occur at long intervals and are extremely torrential.

"Conditions at this station during 1909 were fairly good up to the middle of August, when heavy rains fell in the Imperial Valley and surrounding country. A considerable flood occurred on New River, washing out the earth approaches to the bridge, and changing the channel so completely that measurements made prior to August are not comparable with those that will be made later. Probably the channel was fairly stable after October 1, 1909, but sufficient discharge measurements have not been made to define the new rating curve. Estimates of flow are therefore withheld."

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* "Abstract of Data, No. 4."

† *Water Supply Paper No. 300*, U. S. Geol. Survey, p. 411.

‡ *Ibid.*, p. 415.

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The last reported measurement in 1909 was made on July 30th, and the only one since that date was on February 4th, 1910.

The information obtained from such gauging stations, although no doubt the best that circumstances afforded, is certainly not sufficiently reliable to justify its use in the calculation of coefficients in a formula intended for general application.

The rainfall and run-off data are even less reliable. Referring to the Imperial Valley, F. T. Robson, Assoc. M. Am. Soc. C. E., says:*

"In such desert country, where the rainfall is scant, that which does occur is frequently in intense storms or in local cloudbursts. Monthly records, therefore, are of little value as indicating the probable run-off, and each storm at each observation station must be considered, instead of the monthly totals."

Under such conditions, any estimate of the total precipitation on a drainage area of 7 020 sq. miles is subject to enormous errors, as the areas covered by these very intense storms cannot be known, and the resulting run-off is so uncertain that it cannot even be guessed at intelligently.

Thus, in the attempt to determine the evaporation from Salton Sea, there is just one element which permits of exact measurement, *viz.*, the fall in the water surface, and this, it may be assumed, is accurately known. The inflow through two channels has been only crudely measured, and the rainfall and resulting run-off have been little better than guessed. Yet, after 3 years of elaborate measurements, refined analysis, and hair-splitting numerical computations, Professor Bigelow uses such figures as a basis for the ratio which is the sole practical result of his investigation, and the authors quote it to the tenth of 1 per cent.! The involved and complicated discussion in which the Reno and Salton Sea observations have been buried has given a false idea of their precision and of the value of the conclusions drawn from them. We must not be misled by mathematical intricacy masquerading as profound scientific analysis.

Referring now to Mr. Robson's computations from the Salton Sea data, which the authors have cited, it seems to the writer that an incorrect use of some of the figures has been made. Mr. Robson adds the observed rises in the surface of the sea and assumes that the total represents the discharge from the Alamo and New Rivers. This does not seem to be warranted. It is conceivable that the discharge from these streams, together with inflow from other sources, might be just sufficient to maintain the water level constant, in which case, by Mr. Robson's method, the discharge of the rivers would be nothing. His estimate of accretions to the sea from rainfall, though no doubt the best that could be made from the existing information, is too uncertain

* *Transactions*, Am. Soc. C. E., Vol. LXXVI, p. 1521.

to admit of its use in the determination of the evaporation depth from Salton Sea. Mr. Comstock.

As a result of a careful examination of all the data and arguments, the writer feels justified in saying that nothing has yet been adduced to show that the evaporation from a lake surface is less than from a pan floating in the lake (except for possible difference in temperature of the water inside and outside the pan), much less to establish the ratio of evaporation depths to the third decimal place.

It has not even been shown that there is commonly a difference of temperature between the water in a floating pan and the water in which it floats, and the writer believes that such difference, if it exists at all, will be insignificant, unless the pan is very shallow. A. A. Weiland, M. Am. Soc. C. E., now State Engineer of Colorado, maintained continuous evaporation observations for 1½ years, in 1908-09, on two reservoirs near Pueblo, Colo. He used cubical pans, 3 by 3 by 3 ft., floated in the reservoirs. Concerning these observations, he writes, in a personal letter, as follows:

"For some time we took both the temperature of the water in the pan and in the reservoir, but this was abandoned on account of the two readings being practically the same."

We come now to Subsidiary Conclusion (*d*): Here the authors apparently have allowed their wish to find a simple relation between evaporation depth and some meteorological element commonly of record, to outweigh their scientific judgment. At the end of their discussion of the relation between evaporation depth and monthly mean temperature they say, on page 1767:*

"* * * the conclusion seems warranted that (at least for the Great Plateau and for the complete cycle, averaging a year) the monthly depth of evaporation increases with the mean monthly temperature, usually by an approximate 'straight-line' relation."

The writer contends that this conclusion is not justified by the authors' own diagrams, even if their premises are accepted, which in itself is impossible.

They cite six stations in Texas and New Mexico, at which measurements of evaporation from pans have been made, and they say concerning them:

"A study of these data * * * develops the fact that for each station there exists a stable average relation between its monthly depth of evaporation and its monthly mean temperature; * * *

"It is well known that many other conditions besides temperature affect the depth of evaporation, such as prevalence and velocity of the wind, humidity, vapor tension, barometric conditions, etc. However, these other conditions are almost entirely unknown in most cases

* *Proceedings*, Am. Soc. C. E., for September, 1915.

Mr. Comstock. where engineers are called on to estimate the probable annual evaporation—whereas mean temperatures frequently are of record. It is fortunate, therefore, that the joint effect of all the climatic conditions except mean temperature is so small (either because of the relative unimportance of each, or because some tend to counteract others) that a direct comparison of mean temperature with evaporation depth at any station on the Great Plateau leads to an average relation so stable and so essentially accurate that its use is justifiable in estimating evaporation depths, even when unaided by a knowledge of the other climatic conditions which affect evaporation."

These statements are of the sort generally classified as "important if true". If they are to be accepted, the departures of observed evaporation depths from the curves drawn on the diagrams must be regarded as accidental errors, and are subject to discussion as such. The writer, therefore, has prepared from each of the diagrams, El Paso, Albuquerque, Carlsbad, and Elephant Butte, a table showing the departure of each observed evaporation from the corresponding curve, and from these has computed the probable error of a single observation at each station. The evaporation depths were scaled from the diagrams.

At El Paso the mean departure (disregarding sign) of the observation from the curve is 1.05 in., or 15% of the mean monthly evaporation. The probable error of any single observation is 0.89 in.

At Albuquerque the mean departure is 1.107 in.—again 15% of the observed mean monthly evaporation—and the probable error of a single monthly observation is 1.04 in.

At Carlsbad the mean departure is 0.53 in.—13% of the mean monthly evaporation—and the probable error is 0.52 in.

At Elephant Butte the mean departure is 0.90 in.—12% of the mean monthly evaporation—and the probable error is 0.80 in.

Similar computations for Austin and Lake Avalon were not made because of the small number of observed values at those stations.

Such probable errors certainly do not warrant the statement:

"* * * that a direct comparison of mean temperature with evaporation depth at any station on the Great Plateau leads to an average relation so stable and so essentially accurate that its use is justifiable in estimating evaporation depths, even when unaided by a knowledge of the other climatic conditions which affect evaporation."

On the contrary, they point unmistakably to the omission of one or more elements having a direct causal relation with evaporation.

Does it not seem strange, also, that the temperature-evaporation relation should be a straight line at Lake Avalon, and a curve of higher degree at Carlsbad, only 5 miles distant? That out of six stations examined, straight lines are considered satisfactory relations at four, and that other curves must be used at two?

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Up to this point the authors have adhered rigidly to Professor Bigelow's formula and to every deduction he has made from it. In their attempt to establish a simple relation between monthly mean temperature and evaporation depth, they have entirely ignored, not only the Bigelow formula, but all formulas heretofore suggested. Their assumption, that evaporation depth at any station may be expressed as a function of monthly mean temperature only, leads inevitably to the conclusion that vapor tension of saturation, vapor tension at dew point, and the wind term, are functions of the air temperature at the station, and of no other variables. That any combination of these elements, by the Bigelow or by the Dalton formula, integrated over a period of one month, should reduce to a constant multiplied by the monthly mean temperature is not only inconceivable in theory, but is not indicated by the authors' own facts.

The very large probable errors resulting from their diagrams have already been mentioned. In addition, it should be pointed out, as the authors have recognized, that if the linear relation between temperature and evaporation obtains, the cumulative diagrams on Plate XXXIII should be straight lines. As a matter of fact, these curves depart very markedly from straight lines, and all in the same way. The authors say of this:

"It is noticeable that all the curves of Plate XXXIII * * * are of a similar 'ogee' form at all the measured stations, and for a whole year do not depart greatly from a straight line."

It is, of course, possible to draw through any group of plotted points a straight line which will represent the law of their relation better than any other straight line, but this does not justify the choice of the straight line in preference to any other curve. It would seem that the striking similarity of all these mass-curves and their departure from a straight line should have suggested to the authors that their assumed temperature-evaporation relation was incorrect, rather than appealing to them as evidence in its favor.

Turn now to the Piche evaporimeter records, diagrams of which are published on Plate XXXII, and which the authors regard as confirmatory of their assumption: Of them the authors say:

"These evaporimeter diagrams show clearly (as do those of the pan-evaporations at the six stations) that the monthly depth of evaporation varies with the monthly mean temperature, in general in accordance with a 'straight-line' relationship."

A glance at the diagrams will show that, for six of the eleven stations, namely, Rio Grande City, Abilene, El Paso, Fort Davis, Fort Stanton, and Santa Fé, curves similar in character to those used by the authors for the Austin and Carlsbad records would fit the plotted

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In reference to this matter, it is worth while to look into the history of the Piche evaporimeter and the observations made with it, to which the authors have referred. It has frequently been said that the indications of the instrument are equivalent to pan measurements, but no one has cited an ultimate authority for the statement.

The Piche instrument is one of the numerous devices, intended to provide a ready and easily portable means for the measurement of evaporation, which were put forward from time to time before the complex nature of the problem was generally recognized. It was first described under the name *"atmismomètre"*.* It has since been subjected to numerous tests in comparison with other devices for the same purpose, and with erratic and uncertain results. Mr. William Napier Shaw has stated† that there were three difficulties with the Piche instrument: (1) A certain difference of pressure between the air inside and outside the tube is required to force the bubbles through the paper, and this may not be constant; (2) the condensation of water on the sides of the tube at the water surface; (3) the readings are sensibly affected by variations in temperature and barometric pressure.

In 1879, Riegler found the evaporation from a Piche evaporimeter to be 2.03 times that from a free water surface. In October and November of the same year, Kunze found values of 1.05, 1.12, and 1.09 for this ratio; in April, 1880, the same experimenter found 1.49, and in July, 1.37. In 1890, Houdaille concluded:

"Daily evaporation, as measured by the Piche atmometer, is very irregular as compared with that from an evaporating surface more naturally exposed to the action of the wind and nearer the temperature of the air."

Describing the work with these instruments by Professor Thomas Russell, of the United States Signal Service, in 1888, Professor Cleveland Abbe wrote:‡

"Comparing equal surfaces of paper and water the Piches evaporated 1.33 times as much as the dishes when the dishes were full, but the ratio increased steadily up to 2.05 in proportion as the surface of the water in the dishes fell lower and lower.

* * * * * * *

"* * * The different Piche evaporometers agreed with each other more closely than the different dishes of water. The height of water in the tube of the Piche evaporometer or its pressure on the disk of paper made no appreciable difference in the evaporation. These comparisons were all made with apparatus installed in thermometer shelters,

* In Bulletin de l'Association Scientifique de France, in 1872.

† Quarterly Weather Report, Meteorological Office (London), 1877.

‡ *Monthly Weather Review*, June, 1905, p. 254.

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i. e., cubical boxes, three feet on a side, with open louvers, they therefore correspond to a very gentle movement of the wind over surfaces that are protected from the direct rays of the sun.

"An anemometer set up inside the shelter gave velocities only one-half those recorded on the outside. It was found impossible to make any satisfactory allowance for the wind as recorded in the standard location of the anemometer. The average velocity of the wind for a year at all Signal Service stations was estimated to amount to about 8.5 miles per hour, and the general observations of evaporation must be considered as holding good for that velocity in the free air or one-half of that velocity in the shelter.

"The effect of the wind on evaporation was determined by direct experiment, using the 28-foot whirling machine set up in the interior of the Pension Office Building, with which anemometers had been standardized. One Piche evaporometer was suspended in the adjoining quiet air, the other fixed to the outer end of the long arm of the whirling machine and driven at a given rate of motion for half an hour, when both instruments were observed by very accurate weighing instead of the less accurate scale reading. Then the two Piche evaporometers were interchanged and another similar set of observations made. The evaporation from the moving Piche was greater than that from the quiet one by the factors in the following table, which holds good for an average temperature of 83.7° F. and a relative humidity of 50 per cent.:

Velocity. Miles per hour.	Factor.
0	1.0
5	2.2
10	3.8
15	4.9
20	5.7
25	6.1
30	6.3

"If barometric pressure is lowered the evaporation is increased, but no opportunity was offered for repeating these whirling experiments at very low pressures and they may be assumed to hold good for a barometric reading of 30.00 inches. On the other hand the evaporation computed for 30.00 inches was reduced theoretically by Professor Russell for the effect of the low pressure at any given high station by using the ratio 30.00 inches divided by the mean pressure at the station as the barometric reducing factor.

"As the amount of evaporation increases with the temperature and dryness of the air Professor Russell also reduced the observations at Washington to a theoretical value at any other station by using the additional factor

$$A\ p_w + B\ (p_w - p_d)$$

where p_w is the vapor tension corresponding to the wet-bulb thermometer, and p_d is the vapor tension corresponding to the dew-point. Using the monthly means of observations at the eighteen stations occupied by the Signal Service the arbitrary coefficients A and B were deter-

Mr. Comstock. mined so as to satisfy the whole range of observations, and Professor Russell found $A = 1.96$, $B = 43.9$.

"It will be seen, therefore, that by means of the coefficient 1.33 Professor Russell passed from the Piche to the evaporation from the surface of water in dishes in shelters. By means of the tabular results of experiments with the whirling machine he passed from the wind in the shelter to the natural wind outdoors. By means of the barometric coefficient $\frac{30}{b}$ he passed from the lower to the higher altitudes. By the coefficients A and B he passed from the temperature and relative humidity prevailing in the shelter at Washington to the conditions prevailing at any point in the United States. Of course, however, this whole process was a series of approximations, and although it is the best that has yet been done, still it is in great need of revision.

"The amount of evaporation from natural surfaces exposed to full sunshine can not be estimated even roughly from the records of observations made within instrument shelters. The latter may apply fairly well to forest areas, cloudy weather, and shaded mountain sides, but work in direct sunshine is needed in order to supplement the work done by Professor Russell. Such measurements under natural conditions have indeed been recorded by several investigators, notably Stolling, at St. Petersburgh, FitzGerald, at Boston, the Army Engineers, at Milwaukee, Wis., and more recently Carpenter, at Fort Collins, Colo. With the first of these results Professor Russell compares his own work and shows that if we assume a velocity of 3.5 miles per hour within the shelter at Boston, or 7.1 miles outside the shelter, then the computed evaporation, 34.40 inches, agrees closely with the observed evaporation, 39.11, for one year. For New York the computed evaporation is 40.60 inches, the observed, at the Croton Water-works, 39.21 inches.

"For Milwaukee during three years, 1862, 1863, and 1864, but only during the warmer months of each year, observations were made by the Chief of Engineers by weighing a large shallow vessel filled with water set up inside a thermometer shelter. The mean of these three years, for the months of June to September, gave a total for these four months of 20.60 inches, the corresponding total computed by Professor Russell is 14.70, a large difference for which no explanation is offered. For the corresponding months at Chicago, in 1888, the Piche evaporometer gave 23.87 inches, and the theoretical formula for normal atmospheric conditions gave 19.60 inches.

"In both cases it is likely that the normal conditions assumed by the formula differed largely from the actual conditions of the years in question. In general, therefore, although Professor Russell's formula will hold good for the moist climate of the eastern United States it may give too small values for the hot, dry climate of the interior. He estimated its accuracy as correct within 20 per cent., but added that it must be remembered that the formula and the figures given by him for all Signal Service stations represent only the possibilities of evaporation under normal conditions, and not the actual evaporation occurring from natural surfaces."

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From the experiments and formula just described, and by the use of psychrometer readings at various stations, have been computed the tables of evaporation generally published in textbooks, *e. g.*, "Public Water-Supplies", by Turneaure and Russell; "Irrigation Engineering", by H. M. Wilson. In the former work the table is headed "Calculated Monthly Evaporation", but in the latter the impression is given that the tabular figures are the results of direct observations with the Piche instrument. Unfortunately, many people know of these tables who know nothing of the method of their construction, and, therefore, they accept them as the last word on the subject.

Professor Bigelow says:*

"We used six improved Piche evaporimeters at Reno, and compared them directly with the evaporation from the pans at the same elevations and under like conditions, with the hope of substituting these more sensitive instruments for the large pans. * * * At Reno the evaporation was rapid enough to exhaust the water in about three hours in strong winds during the afternoon, so that the rate of the fall of the water was about 55 times greater in the tube than in the open pans, an advantage in accurate reading, *provided the ratio is a constant.*"

The italics are his. He then presents a table of values of this ratio, the range being from 41.7 to 76.5, with a mean for all of 56.2. Obviously, the indications of the instrument are worthless for the purpose of measuring evaporation.

Professor Bigelow then computes "that the evaporation averages 1.177 times faster from each cm^2 of paper to each cm^2 of the free water surface". He concludes: "It was a disappointment to find that this promising piece of apparatus must receive further study and development."

From the foregoing account of the history of and experience with the Piche evaporimeter, it is clear that its records, on which the authors rely so confidently to support their assumed evaporation-temperature relation, are unworthy of serious consideration. Even if they were dependable, six of the eleven stations used by the authors distinctly negative the straight-line assumption.

Having shown that at four of the six pan-evaporation stations used by the authors the assumption of evaporation as a function of mean monthly temperature only, leads to absurdly high probable errors, and that the Piche evaporimeter records are worthless and do not support the assumption, even if they were not, the writer believes he is justified in discarding Subsidiary Conclusion (*d*).

The authors' discussion of Subsidiary Conclusion (*e*), namely, relation between evaporation depth and elevation above sea, is clouded

* *Monthly Weather Review*, February, 1908, p. 38.

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by the intimate admixture of the assumed evaporation-temperature relation. Here, again, they ignore Professor Bigelow, who wrote:*

"There is no evidence that water in pans of the same size evaporates faster on the Plateau levels, 4,000 feet, than at sea level, and the formula should not contain any barometric pressure term."

In this respect they were wise. Professor Bigelow's failure to find a barometric term is not surprising, in view of his obscure and doubtful reasoning, and his conclusion on this point is at variance with experience and experiment.

In 1789, H. B. de Saussure made comparative observations on the Col du Géant, where the barometric pressure was 18 inches 9 lines, and at Geneva, Switzerland, where the barometer stood at 27 inches 3 lines, from which he concluded that "other things being equal, a lowering of the pressure of the air by approximately a third makes the quantity of evaporation more than twice as great".

Numerous laboratory experiments have shown beyond question that the air opposes a mechanical obstacle to the escape of liquid particles in the form of vapor, and that this obstacle is greater at high than at low pressures. It has been usual to introduce the barometric pressure in such a way as to make the rate of evaporation inversely proportional to the pressure. This is arbitrary and, although perhaps sufficient to cover all natural conditions, is certainly not correct, as it would result in an infinite rate of evaporation in a vacuum, no matter what the temperature. However, if it is even approximately correct, the relation sought by the authors between evaporation and altitude above sea level must be very complex, because it contains implicitly the relation between altitude and barometric pressure.

The authors have not established any explicit relation between altitude (or barometric pressure) and evaporation, but have put forward a double relation involving altitude, monthly mean temperature, and evaporation. Since, for reasons already given, the temperature-evaporation relation must be rejected, the altitude-temperature-evaporation relation falls with it.

The net results of the paper, in respect to the subsidiary conclusions, may be summarized as follows:

(*a*).—Relative evaporation depths from pans of different sizes.—No relation established; and no differences shown to exist except when the water temperatures differ.

(*b*).—Relative evaporation depths from land-pans and floating pans.—Very few acceptable data submitted; and these indicate a ratio of from 82 to 85 per cent.

(*c*).—Relative evaporation from reservoir surfaces and pans floating thereon.—It has not been shown that there is any difference, nor has any good reason been advanced why there should be.

* *Monthly Weather Review*, July, 1910, p. 1133.

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(*d*).—Relation between evaporation depth and mean temperature.—None has been shown, and it is practically certain that none exists unless other meteorological conditions are included simultaneously.

(*e*).—Relation between evaporation depth and elevation above sea.—Same comment as on (*d*).

We come now to the authors' Principal Conclusion, namely, the yearly depth of evaporation from Lake Conchos.

They measured the evaporation from one floating pan for an aggregate of 112 days distributed through 6 months, and from another floating pan for 10 days in all, distributed through 3 months. These pans were about 2 miles apart, and both were within 2½ miles of the eastern end of a reservoir which, when filled, will be 25 miles long and will cover about 60 sq. miles, and which, at the time of the observations, covered 16 sq. miles. After ultra-refined speculations as to the differences in evaporation from 2, 3, and 4-ft. pans, and insisting on distinguishing between square and round pans used for such measurements, they calculated the annual evaporation over the whole reservoir from a few days observations in one corner of it.

From the observations on floating pan No. 2 (112 days) the authors estimate the total evaporation for 6 months, January to June, inclusive, to be 48.31 in. Using their estimated percentage, 50.4%, for these months, the annual evaporation is found to be 95.85 in.

The writer has calculated the percentage distribution of evaporation at thirty stations in the United States, and has taken the mean for each month. The result shows 46% of the annual evaporation for the months, January to June, inclusive. If this figure is used, the annual evaporation at Lake Conchos, calculated from pan No. 2, is 105.02 in.

The authors' estimated evaporation from measurements on floating pan No. 4 (10 days observations) is 15.50 in. for the months, January to March, inclusive. Their estimated percentage for these months is 17.8%, giving an annual evaporation depth of 87.08 in. The writer's percentage for these months is 13%, giving 119.23 in. annual evaporation.

From these quantities, which are the only real data in the case, the annual evaporation loss is 91.46 in., using the authors' percentages, or 112.12 in. if the writer's percentages are correct. Not one sound reason for reducing the evaporation depth below at least the lower of these figures, has been advanced.

It is not improbable that the rate of evaporation differed to an important degree from point to point on the lake, but the authors' observations did not show this, and, in the absence of information on this point, they should have accepted the results of their measurements instead of seeking to reduce them, on entirely unjustified grounds, to conform to a preconceived notion.

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It seems hardly probable that the various elements involved in a determination of evaporation by balancing inflow and outflow can be known with sufficient accuracy to warrant the use of this method. There must have been much uncertainty as to the volume stored and as to rainfall and run-off. For 4 months—October to January—the estimated precipitation on the lake surface was more than 2 in., and for 7 months—October to April—more than 3 in. These figures are based on measurements at two stations 25 miles apart; and, in a region of torrential storms, the mean of two stations cannot be safely taken as the average precipitation over a considerable area, nor can the local run-off be ignored.

Even if the authors' method is followed, there is some doubt as to the correctness of the results which they have reached. Their percentage of annual evaporation for October to January, inclusive, is 21.7%, and for October to April, inclusive, 44.1 per cent. The corresponding figures from the writer's calculations are 18 and 37 per cent. These give 66.89 in. evaporation from the 4 months' observations, and 68.65 in. from the 7 months' measurements, or a mean of 67.82 in. This is nearly one-fifth more than the authors have found, and is believed to be based on percentages more probable than they have used.

The writer believes that all evaporation formulas thus far suggested are erroneous as to form, because of the manner in which the wind term is introduced. The Dalton formula is the basis for all except Professor Bigelow's various forms, and these have no rational justification. In the Dalton and allied formulas the rate of evaporation is made to depend chiefly on the factor $(e_s - e_d)$, where e_s is the vapor tension of saturation at the temperature of the water surface, and e_d is the vapor tension at the dew point of the air. There is every reason to believe that this form is correct. The effect of the wind is to clear away the saturated or nearly saturated air, leaving in its place drier air, that is, air in which e_d is smaller. The wind term, then, should be introduced by making e_d a function of wind velocity, air temperature, and psychrometer difference, and e_s a function of water temperature only. In such a formula it is believed that the apparent anomalies in evaporation calculations will disappear.

It is useless to urge that a formula must contain only those elements that are commonly of record. If we are to calculate evaporation, or anything else, we must take into account all the elements which influence the effect in question. If we do otherwise, we mislead ourselves by a pseudo-precision which reminds one of the man who paced the diameter of a circle and computed the area to five decimal places.

It would be extremely convenient if evaporation depended only on monthly mean temperature, but that does not justify such an assumption.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

THE FAILURE AND RIGHTING OF A MILLION-BUSHEL GRAIN ELEVATOR

Discussion.*

By David Gutman, M. Am. Soc. C. E.

Mr. Gutman.

David Gutman,† M. Am. Soc. C. E.—The speaker once had an experience with the sinking of the foundation of a building which, although of a different nature from the grain elevator under discussion, had one point in common, in that the structure acted as a monolith.

About 4 years ago, he was Designing Engineer for the architect on the Taft Hotel, at New Haven, Conn., a fourteen-story structure with two basements. The framework was of steel, and the floor-slabs were of the long-span type formed of concrete beams, 16 in. on centers, with a tile filler between. The foundations consisted of cast bases resting on reinforced concrete piers, the piers resting on sand. In the boiler-room the tops of these piers were about 4 ft. below the water line. The piers were placed by draining the water to a sump and pumping day and night. The basement was then water-proofed by placing felt water-proofing on a concrete mattress. The water-proofing was in turn held down by a concrete floor, the reinforcement being inverted, as the load—that is, the water pressure—was from below.

Early one morning, the speaker, who was in New York, received an urgent telephone call to visit the job at once, and on his arrival found that one of the concrete piers had dropped more than 2 ft., taking the cast base with it and leaving the column suspended in mid-air. The column itself had sunk about 2½ in.

* This discussion (of the paper by Alexander Allaire, M. Am. Soc. C. E., published in December, 1915, *Proceedings*, and presented at the meeting of February 2d, 1916), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† New York City.

Mr. Gutman.

The column was of the I-type, and had a girder running into each flange, the depth of the girders varying from 15 to 20 in. on the different floors. It was evident that the column no longer acted as such, but simply as a link between the two girders, making them one continuous girder of 32 ft. span, instead of two girders of 16 ft. span each. No wind bracing had been provided, other than a very stiff girder connection to the columns. One of the features of this connection was a 6-in. outstanding leg for the angle-seat and top-lug, having four rivets instead of the usual two. It was this stiff connection, as well as the excellent floor-slab (from 7 to 9 in. deep), which made the continuous action possible and prevented a very serious collapse.

The cause of the sinking of the foundation—a concrete pier 10 by 10 ft.—was as follows: The felt water-proofing had been pierced in some way, and this allowed a gradual seepage of water which accumulated in the cellar. In order to get rid of this water the pump was again set going, but, through negligence, the damage was not repaired at once, the work being delayed almost a month. Of course, some sand was pumped in with the water, and gradually the pier was undermined.

Two heavy plate girders were placed on opposite sides of the column, spanning to the two good piers on each side. These girders were then riveted to the column and jacks were placed under the ends. By these jacks, the column was pushed up about $\frac{3}{4}$ in. It was not considered wise to raise it the whole amount of the settlement—$2\frac{1}{2}$ in.—as this would have cracked the plaster on the upper floors, most of which had already been placed. The piers on each side showed no settlement whatsoever, either before or after the jacking.

AMERICAN SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

A REVIEW OF THE REPORT OF CAPTAIN ANDREW TALCOTT CHIEF ENGINEER MEXICO AND PACIFIC RAILROAD EASTERN DIVISION FROM VERA CRUZ TO MEXICO EXPLORATIONS SURVEYS ESTIMATES 1858

Discussion.*

By W. T. Ingram, Esq.

W. T. Ingram,† Esq. (by letter).—The writer has read Mr. Low's paper with deep interest. A great many of the data which he has gathered together, it is thought, have never before appeared in print; in fact, the present management of the railway was unaware that such a mass of information was still extant. The paper will prove a valuable addition to the Company's archives, and will be very interesting reading to those engineers who have been directly or indirectly connected with this, or, in fact, with any railway in Mexico. Mr. Ingram.

This railway, opened for public service 43 years ago, is a lasting monument to the skill and energy displayed by the pioneers, and stands to-day a model of railway construction in Mexico.

Not until recent years has there been any serious attempt to improve the grades and alignment to meet the growing traffic, and it has been found that the most that can be done is to reduce the grade on the table-land, that is, from Esperanza to Mexico, from 1½ to 1%, and by building a high-level bridge over the Metlac River to save the expense of operating trains in and out of the ravine.

It is stated that the project of building a high-level bridge was abandoned—or, at least, very strongly influenced—on account of an

* Discussion of the paper by Emile Low, M. Am. Soc. C. E., continued from February, 1916, *Proceedings*.

† Res. Engr., Ferrocarril Mexicano, City of Mexico, Mexico.

Mr. Ingram. earthquake which occurred while the project was under consideration; if this is the case, it was most unfortunate that the earthquake should have occurred at such an inopportune moment, for during the writer's long residence of nearly 28 years, spent wholly between the City of Mexico and Vera Cruz, he has never known, nor even heard from "the oldest inhabitant", of any earthquake which would have imperiled a high railway bridge, that is, of course, in the neighborhood of Orizaba. On the table-land he has experienced several severe disturbances, but these are reduced in intensity as the coast is approached; in fact, a severe earthquake in the City of Mexico is barely noticeable in Vera Cruz.

If it was unfortunate that the high-level bridge was not built in 1866, it is still more unfortunate that the Revolution, which commenced in 1910 and still continues, has deferred its construction indefinitely, due to the fact that, after long deliberation, it was considered that a bridge of such magnitude would be very easily destroyed, with, of course, disastrous consequences. Fortunately, the present Metlac Bridge and practically all others have escaped serious damage, but the danger has been ever present for several years past, and very great anxiety has been felt by all concerned; how much more so would this have been the case had the bridge been nearly 350 ft. high?

Some day, of course, the bridge will be built, as the development in and out of the *barranca* is perhaps the most dangerous part of the railway, and mile for mile the most expensive to operate. When this day arrives, it is to be hoped that the Mexican people will have developed into a peaceful and law-abiding nation.

Mr. Lyons, in his report, condemned the route *via* Las Vegas and Jalapa, stating that the country was most unfavorable and that all cuttings would be in volcanic rock. His prognostication, however, has not been fulfilled, as the Interoceanic Railway, a narrow-gauge (36-in.) competing line with the Mexican Railway, follows the route which Mr. Lyons considered so unfavorable, and, moreover, the grades do not exceed 2½%, as compared with 4% (both uncompensated) of the Mexican Railway, the maximum curvature on both lines being practically the same, namely, 100 m.

The Interoceanic as it stands to-day is 50 km. longer than the Mexican Railway, but some 9 years ago a line was actually located from Las Vegas *via* Jalapa, to the foot of the mountain, using the same grade, namely 2½%, but compensated with maximum curvature of 200 m. The distance was shortened considerably, but this location involved the construction of an entirely new line for a length of some 125 km., consequently the project is hardly likely to be entertained favorably for some years to come. As a matter of fact, there is less rock on the Interoceanic route; the lava flow from the "Cofre de Perote", which has to be crossed, no doubt on first acquaintance looked very formidable, but its natural fall happens to fit the grade, and the cuts and fills are relatively light. As the original scheme was to connect the City of Mexico with Vera Cruz, to a great extent irrespective of the intervening towns, except Puebla, which very rightly has been connected to the main line by a branch, the writer believes that, had the Jalapa route been studied as thoroughly as that of Orizaba, the former would have been selected, due to the more favorable grade. Mr. Ingram.

On the other hand, however, the Orizaba route passes through towns and villages of greater importance and a much more cultivated and productive part of the country; consequently, on the whole, and in the light of after events, the selection of the route of the first railway in Mexico was a happy one. Jalapa is of no commercial importance, it being merely the seat of the State Government, whereas Orizaba is a flourishing town and the center of the cotton and jute industries, due to its abundant supply of water power.

On page 2602,* Mr. Lyons' report states that the material known as "tepetate" is the débris of the rock which forms the material of the Cordilleras; but, as a matter of fact, it is consolidated volcanic mud, and has never by any chance been used as a substitute for sand in making mortar; it is absolutely useless for such a purpose, or, in fact, any other except when quarried into blocks for building purposes and for temporary ballasting of railways. The writer uses the word "temporary" advisedly, for tepetate, with constant tamping, is soon converted into mud in the wet and into intolerable dust in the dry season.

* *Proceedings*, Am. Soc. C. E., for December, 1915.

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PAPERS AND DISCUSSIONS

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SECURE SUBWAY SUPPORTS

Discussion.*

BY MESSRS. H. G. MOULTON, RICHARD A. FIESEL, J. H. O'BRIEN, AND B. C. COLLIER.

H. G. MOULTON,† ESQ. (by letter).—The method of shoring and street support discussed in this paper is excellent, and fully entitled to classification under the heading "Secure Subway Supports". Mr. Moulton.

The essential feature of safety in this method does not lie in the massive cantilever tower supports in the center, but in the continuous steel longitudinal beams supported thereon. The same ends of safety may be attained—and it is probably open to question as to whether they may or may not be attained at an equal or lower cost—by supporting the continuous beams on transverse girders resting on posts which are in turn securely braced so that they act as retaining timbers for the vertical rock walls of the cut.

Any method of shoring which does not remove the possibility of a sudden local collapse in the side-walls of the excavation is dependent for its safety on continuity of the decking support, so that the decking will carry over if a local rock-fall destroys any one essential supporting member. The same criticism is applicable either to transverse box girders resting on posts adjacent to the walls, or to center supporting towers. In each case any particular support may be destroyed by blasting or by caving of the side of the excavation, and in such an event the entire load of two panels must be transferred immediately, with a fair margin of safety, to adjacent supports.

The method of shoring discussed herein makes no provision for supporting the side-walls of the excavation. The method, therefore,

* This discussion (of the paper by A. B. Lueder, M. Am. Soc. C. E., and W. J. R. Wilson, Esq., published in January, 1916, *Proceedings,* and presented at the meeting of February 16th, 1916), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† New York City.

Mr. Moulton. is not a safe one unless definite provision is made for underpinning buildings or taking care of intersecting street crossings in such a manner that no accident will happen in case the unsupported rock wall caves in. In doubtful ground it would seem necessary to open the center of the excavation in advance so that the character of the rock could be determined and provision made for underpinning buildings before the side-walls are cut vertically.

In Manhattan schist such as commonly found in New York City, there may occur seams dipping into the cut at a steep angle, carrying so much talc that they present a distinctly defined plane with practically no frictional resistance against sliding. Should such a seam occur, with a strike parallel to the cut, and dipping in such a manner that it would be cut across or nearly exposed at the bottom of the excavation, it would be quite possible to have a very serious slide extending over a great distance. Such a slide might bring down a number of the supporting towers placed in the center of the cut, as in the method now under discussion, and thereby bring down the whole system.

In regard to the remarks made by the authors in reference to excessive loads on the decking—that in such cases the Fire Department is probably the worst offender—it has been the writer's general observation that the contractor himself is apt to be the worst offender. With the writer, it has not been an uncommon occurrence to stand at the side of one of the warning signs prohibiting 8-ton trucks from passing, and at the same time observe a contractor's truck, weighing with its load nearer 15 tons than 8 tons, go by at the maximum speed of which it is capable.

The writer takes very decided exception to the authors' main conclusion—that the safety of city streets during subway construction will be better guaranteed if a comprehensive design of the street supports, made by competent engineers, is bid on as a part of each contract. The shoring system in subway excavation is an essential part of the method of construction, and the contractor must devise that system to fit with his usual methods of work and his equipment. It is entirely possible to handle subway excavation safely in a great many different ways. The contractor may use smaller timbers and plenty of them, with good detail, working in small units and keeping his steel structure close to the face. Or he may use large units, so firmly braced that they can stand the shocks of blasting or caves. In this method very great attention must be paid to detail of connections. Or he may provide a continuous decking support which will carry over in the event that he looses any particular point of support. Different contractors have gangs of men trained to timber in certain ways. One firm, for example, has a method of sinking pits down to subgrade and placing supporting posts therein before excavating the main body of the material. This method might not prove satisfactory to another contracting firm, on account of not having a trained organization used to handling it. Mr. Moulton.

Generally speaking, the contractor who takes the financial responsibility of the work is entitled to do it in any way he chooses, provided he does it in a way that the supervising engineer can accept as safe, from the standpoint of the public. Contractors often develop, under the spur of financial considerations, very interesting, important, and valuable new methods of shoring. For the supervising engineer, or representative of the public, to enter into the field of temporary shoring design would be on his part a trespass on the economic functions of the contractor. The proper function of the supervising engineer ends with designing the permanent work, seeing that it is placed in accordance with specifications, and that while it is being placed the work is done in such a manner that the public safety is properly served.

There are a few points in this paper which are worthy of further mention. The excellent treatment of the I-beams should be noted. It will be observed that the beams are in pairs bolted together against a timber filler block, and also that the adjacent pairs are stayed with diagonal braces and steel rods with turnbuckles to resist tension. The steel members, in this manner, should gain stability and resistance against overturning.

In regard to blasting, it seems strange to a mining engineer that this should be considered as so much of a problem in connection with its effects on the shoring structure. In removing ore underground by the square set timber system, where the lower part of the face is advanced ahead of the upper part, it is not uncommon to fire from 40 to 50 shots at a round in a face 50 ft. wide. The holes may be from 2 to 10 ft. from the nearest supporting timbers, and the blast may be heavy enough to break the rock into pieces sufficiently small to be sent down the chutes and trammed out in small cars. The nearest timbers are usually protected by spiking on old planks temporarily. Instead of attempting to keep the timbers sufficiently far from the face to prevent them from being struck by rock from blasts, it is the usual mining practice to design the timbering system in such a way that posts and caps have end bearings to enable them to resist the blows of flying rock; and the connections are also designed in such a manner that the timber system as a whole is not affected if one or two posts or caps should be broken by flying rocks. This point is raised only as an interesting example of the differences in methods developed by subway contractors and mining engineers, which differences, on analysis, would probably prove to be due to material variation in the conditions under which the work is to be carried on, or to the labor and organization available.

Mr. Fiesel. RICHARD A. FIESEL,* ESQ.—The speaker desires to express his appreciation of this excellent paper. The complexity of the subway structure, the condition of the rock, and the magnitude of the work on Section 13 demanded the attention of intrepid men of sound engineering ability. The structure designed by, and built under the direction of, Messrs. Lueder and Wilson was put to a severe test on one occasion when a blast displaced a tower. The roadway dropped less than 13 in. An examination showed that the superstructure was intact. The adaptability of this structure to the conditions encountered on that part of Section 13 where it was used proved good judgment in its selection.

The speaker is not of the opinion that a comprehensive design of street supports, made by competent engineers, will better guarantee the safety of the city streets, if bid on as a part of each contract, because the shifting of the responsibility for the safety of these structures from the contractor to the City is likely to have an undesirable effect, and may lead to conditions fraught with danger. The authors' type of structure is a striking example of what the contractors and their engineers are doing to guarantee the safety of the city streets. Knowing that efforts such as these are being made, it would not be wise for the City to launch out on the proposed venture.

There are other considerations: the type of temporary structures used by the contractor for shoring the sides of an excavation, or supporting the roadway, or both, is sometimes an eleventh hour tentative selection. Any type selected must be adapted to the contractor's equipment and method of operation. Sometimes the tentative design is materially modified as a result of studies made as excavation progresses. The contractor may enlarge his equipment or may entirely change his method of operation. The inclusion in the contract of anything affecting this freedom of selection, modification, or operation, would place an unjust burden on the contractor.

A comprehensive design of roadway supports, included in the contract as a separate item, would render the City liable for the safety of the structure, wherefore, in order to protect itself against liabilities arising from possible failures, the City would be compelled to submit designs, similar, in all probability, to those in use to-day, but embodying a factor of safety unwarranted by the conditions encountered, thus adding enormously to the cost of the permanent structure.

Mr. O'Brien. J. H. O'BRIEN,* M. AM. SOC. C. E.—This is a most valuable and timely paper. The speaker, however, is inclined to doubt the practicability and wisdom of the main conclusion if he is correct in understanding that the authors mean to put the design of a scheme of

* New York City.

temporary supports wholly on the shoulders of the Public Service Commission. Mr. O'Brien.

Under such an arrangement, it is not improbable that one more obstacle would be added for the ingenuity of the expert contractor to overcome in planning the execution of his work.

The scheme would undoubtedly aid an inexperienced contractor, but inexperienced contractors should not be permitted to undertake such work, irrespective of their financial ability.

An engineer charged with the responsibility of awarding contracts in private work would not risk an award to a company, the officers or members of which had had no prior experience in the work.

The speaker recalls an instance where a public commission undertook to design a shut-off dam which formed the basis of part of the contractor's tender.

When the time came to build it, the contractors refused to take the responsibility of carrying out the commission design, and submitted an alternate which was not acceptable to the commission. At the suggestion of the contractors, an eminent consulting engineer was called in. He prepared a design acceptable to both parties, and it was carried out without difficulty.

The speaker is fully mindful of the responsibility of the public body in the case of temporary street supports, but is inclined to recommend that it be a mandatory stipulation of contracts for subway work that the contractor shall obtain the formal approval of the commission for a system of supports designed by him, based on specifications defining loading, permissible unit stresses, and other essential restrictions of good design which should be embodied in the specifications of the contract on which he tenders.

B. C. Collier,* M. Am. Soc. C. E.—This paper is very pertinent at this time, when the subject of underground railways is being considered in so many sections of this and other cities; and, especially under such conditions, the conclusion reached by the authors warrants the fullest consideration. Mr. Collier.

They have shown that their design of street supports, in rock cuts similar to those found in New York City, is most excellent and one that warrants the fullest consideration for any locality; but it should be borne in mind that a design applicable in one locality may not be utilizable in another, due to sub-surface structures, or for other reasons.

The authors, however, in their main conclusion, call attention to a point which, in the speaker's opinion, is almost axiomatic, in their suggestion that the engineers of the commissions (or other supervising bodies) call for bids based on previously prepared plans for shoring

* New York City.

Mr. Collier. the cuts and supporting the surface. This suggestion will probably be objected to by numerous engineers who will cite that:

First.—It will not allow the contractor the full scope of his ingenuity or the benefit of his experience.

Second.—It will relieve the contractor from his responsibility, and throw the burden on the engineer.

The speaker does not believe that either of these objections (if raised) can stand the "spotlight" of careful analysis. Certainly, no one would do anything to prescribe the ingenuity of the contractor or his engineers, and the speaker cannot see in what way he would be prescribed by having such suggestions made.

The speaker does not go as far as the authors and agree that the engineers should submit a definite plan of shoring, for experience has shown that in most subway cuts each portion of the work is a question unto itself, and one that demands more or less individual treatment; but he believes that suggestions based on careful study of the situation could be made, which, in themselves, would call for a unit of measurement and a basis for payment. By submitting such proposed plans, and specifying that the contractor might make any modifications or substitutions which would pass the scrutiny and meet the approval of the engineers, the latter would not deny the contractor the benefit of his ingenuity or experience, because he could then compare the proposed scheme with any other he might have in view and govern his bid accordingly, thereby giving him a still further advantage over his less experienced competitor. It must be borne in mind that the preparation of plans, for a work of such large proportions as the usual subway contract, involves the study and thought of numerous men for months, and that the contractor has only a few days in which to analyze the conditions and prepare a bid under which a contract is signed, which contract demands a rigid fulfillment on the contractor's part of all the obligations he has to assume in so doing. The speaker holds, therefore, that anything that can be done by the engineers to prevent the contractor from having to take unusual risks is to the advantage of all parties, and that the establishment of a unit price for such work as "timbering" would be a "long step" toward that end. The engineers would also be directly benefited in that they would have more freedom of action to make such changes or increases as they might feel that the situation demanded, by being able to offer direct compensation to the contractor for doing this work.

It must be borne in mind, also, that all information furnished to the contractor relative to sub-surface conditions is very indefinite; that a plan which might be supposed to govern all conditions would be totally inadequate for the developed conditions; and that any system which demands that the contractor assume all responsibility and financial obligation for this is neither fair nor equitable, and should be changed. The speaker believes that the more closely a specification approximates to a condition under which the risk that a contractor takes is reduced to a minimum, the more satisfactory will be the relationship between the parties working under such specification. Mr. Collier.

In answer to the second objection, the speaker is of the opinion that, by suggesting or approving a plan for timbering, the engineer does not assume the responsibility. Certainly, no one can infer that the engineer, by withholding such written approval, but still giving his tacit acquiescence, has relieved himself from the obligation that should fall on him, of seeing that the work is carried on in a safe and workmanlike manner. How, then, when a plan which is thought out by both parties, and approved by them, is carried out, will the contractor be relieved from his obligations; for it must be remembered that it is his money which is at stake, and that it is he who must "pay the piper" in case of an accident? Why should it be the policy of an engineer to "hide behind the contractor's skirts", and run to cover in case of trouble? Accidents will occur, under the most careful supervision, and the more direct the responsibility an engineer is made to feel, the more precaution will be taken; and as the contractor is not made to feel that he has to bear the financial burden of this precaution, he can offer no objection. This brings into consideration another feature suggested by the authors, namely, that of payment for work done outside of neat lines. One of the greatest sources of contention between engineers and contractors on the New York Subway has been the matter of payment for rock excavation beyond the neat lines, and for the concrete which the contractor is required to place to fill such spaces. Of course, it is true that this same subject has been a "bone of contention" on work from time immemorial, and has demanded numerous solutions in various sections, but this in no wise modifies the conditions that exist in New York City, and should be called to the attention of engineers who will perhaps have similar conditions elsewhere. As pointed out by the authors, probably no city in the country is founded on rock of so treacherous a character as New York, and the speaker believes it is inadvisable to provide for payment, other than the usual overbreakage allowances, unless it is thought that there will be slides of a nature similar to those occurring in New York. In such cases, however, he thinks that the specifications should be drawn so as to provide compensation to the contractor for the expense involved under such circumstances by fixing a unit price for payment, which would be large enough to afford a degree of financial relief, but not sufficiently large to create an incentive on the part of the contractor to cause such a condition deliberately. This would be a further advance toward the end desired by the speaker to see specifications drawn so as to reduce the gambling feature of the contract to a minimum.

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PAPERS AND DISCUSSIONS

A STUDY OF THE BEHAVIOR OF RAPID SAND FILTERS SUBJECTED TO THE HIGH-VELOCITY METHOD OF WASHING

Discussion.*

By George W. Fuller, F. H. Stephenson, and E. G. Manahan.

George W. Fuller,† M. Am. Soc. C. E. (by letter).—The authors of this paper have presented interesting and instructive data relative to important aspects of cleaning mechanical filters, especially with the aid of construction details adopted not only at the Cincinnati plant, but also for those at New Orleans, Louisville, Minneapolis, Grand Rapids, and Evanston. Mr. Fuller.

One of the difficulties which the screen at the top of the gravel in the original design was supposed to correct was doubtless caused by the jet action of the entering wash-water. In consequence of this action, the upper layers of the smaller gravel were seriously disturbed when the total thickness of the layer of gravel was no greater than in the original construction at Cincinnati. The effect of the deeper gravel layers, as interpreted by the writer, is essentially to prevent jet action and thus effect a substantial elimination of the disturbance more or less irregularly of the finer upper gravel layers.

In the earlier designs at Cincinnati, New Orleans, and Louisville, very little trouble with this type of strainer system design seems to have been caused by the quality of the metal, which was what might be briefly designated as "common brass". In the later designs, particularly at Minneapolis and Grand Rapids, effort was made in the

* This discussion (of the paper by Joseph W. Ellms, M. Am. Soc. C. E., and John S. Gettrust, Esq., published in January, 1916, *Proceedings*, and presented at the meeting of March 1st, 1916), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† New York City.

Mr. Fuller. direction of improvement, and bronze, instead of brass, was specified for the perforated plates at the bottom of the gravel and the bolts for holding these plates in place. Under the same specifications, practically speaking, serious trouble from breakage of plates and bolts resulted at Minneapolis; but at Grand Rapids there was practically no trouble, as was the case at Cincinnati, New Orleans, and Louisville. At Evanston, difficulties arose, not with the plates, but with the bronze bolts, and Monel metal was finally substituted for these.

In more recent designs it has been the writer's custom to use, not this type of strainer system, but perforated pipe in which the holes are staggered on the lower quadrant. This allows the wash-water to enter the filter in a downward direction about 45° from the horizontal, with the result that the entering stream strikes the filter floor and is deflected upward as a broken stream substantially free from jet action. This type of strainer system was probably first used by James H. Fuertes, M. Am. Soc. C. E., at Harrisburg, Pa., in 1905. The writer used this perforated pipe strainer system with success in a plant built in Burlington, Vt., in 1907, and in another plant, built at about that time, for the Botany Worsted Mills, Passaic, N. J. So far as known, no trouble has been experienced in any of these plants, but it is probably wise to provide somewhat deeper gravel layers than was the custom in 1905 when the original design for the Cincinnati filters was made.

It is worthy of note that, in the Ira H. Jewell *vs.* Minneapolis filter patent suit, the United States District Court at Minneapolis, in August, 1915, decided that the brass wire screen, such as used in the Cincinnati filters, infringes Claim No. 14 of Letters Patent No. 649 411 which is adjudged valid.

Mr. Stephenson. F. H. Stephenson,* M. Am. Soc. C. E. (by letter).—It was the writer's privilege to be closely connected with the construction of the Cincinnati Filter Plant, both before and after the filters were put into service. While the wire screens were being placed, certain predictions were made relative to their life, which, according to the prophets, ranged from 3 months to 5 years. Some difficulties were encountered in trying to fasten the screens securely to the ridges and, at the same time, keep the screens stretched tightly over the gravel. It took 40 man-hours to place the screens in one filter unit.

The writer has been converted to the idea of not being too insistent about keeping down the uniformity coefficient of the sand, and thinks the authors have shown that the larger particles settle out at the first wash and mingle with particles of similar size in the gravel layer. Some of the analyses made when the sand was being placed in the filters show an effective size of 0.33 mm. and a uniformity

* Cleveland, Ohio.

coefficient of 1.60. The writer recalls that the filters were washed and the top ½ in. of sand scraped off and wasted. That the sand in the filters now has an effective size of 0.39 mm. would indicate that some of the finer particles had been carried off during the many washings, even though the tops of the wash-water gutters are 30 in. above the original sand line. Mr. Stephenson.

E. G. Manahan,* M. Am. Soc. C. E. (by letter).—The details given in this paper regarding the behavior of filter sand and gravel and the losses of head through them when wash-water is applied at various rates of flow are interesting and helpful, and the authors' conclusion to substitute for the wire screen originally put in an additional thickness of gravel is sound. Mr. Manahan.

Although such a screen will probably not be used in the future, further information from the authors as to one of the causes assigned by them for the failure of the screen, namely, corrosion, would be of value. If marked corrosion has occurred in the brass screen during its eight years of service, this fact is important, especially if a like amount of corrosion has taken place in the brass strainer plates. Deterioration of the screen would naturally be expected to result from wear due to the movement of adjacent particles of sand and gravel, rather than from corrosion.

With the wire screen omitted, the Cincinnati strainer system satisfactorily fulfills all requirements for such a system, except that, with an 8-in. layer of graded gravel, as originally constructed, the velocity of the wash-water as it leaves the orifices in the strainer plates is so high that it may slightly disturb the gravel layer and in time cause mixing of the sand and gravel. This velocity at the ordinary rate used in washing is about 11 ft. per sec., and if this should be reduced to 3 or 4 ft. per sec., it is the writer's opinion that no disturbance whatever of the gravel would take place.

Such a reduction in the velocity through the orifices could have been provided for at an expense no greater than the cost of the screen. The cost of the screen and its fastenings was about $0.30 per sq. ft. of net filter area; that of the strainer plates and their fastenings, $0.40; that of placing the screen and plates, $0.33; and that of the concrete ridges in place, $0.20; total, about $1.23. These represent prices paid by the City, and are reasonable, except that the price for placing the screen and plates was too high and that for the concrete was too low.

For the cost of the screen it would have been possible to place a second strainer plate beneath the one used, making both plates, perhaps, a little thinner. The second plate would be of practically the same shape as the first, but placed in an inverted position, with the edges of the two plates in contact and so as to leave a diamond-shaped

* Mount Vernon, N. Y.

Mr. Manahan.

area between them. Then, by a proper choice of orifices in the plates, the greater part of the loss of head could be made to take place in passing through the lower plate, allowing the water to escape at a comparatively low velocity through numerous orifices in the upper plate. The holes would be arranged so that they would not come opposite one another.

This type of strainer system would give a control of the wash-water more nearly positive than that accomplished by using deep layers of gravel, which latter control is somewhat haphazard. However, the cost of the additional plate, although no greater than that of the screen, would considerably exceed, even at times of normal prices for brass, the cost of the additional gravel; although in a new plant this excess would be reduced to some extent by the cost of the extra depth of filter tank required to accommodate the gravel as well as by the cost of added strength in the filter floor and foundations.

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PAPERS AND DISCUSSIONS

THE EFFECTS OF STRAINING STRUCTURAL STEEL AND WROUGHT IRON

Discussion.*

By Messrs. J. A. L. Waddell, Henry B. Seaman, C. A. P. Turner, T. D. Lynch, James E. Howard, H. F. Moore, and F. N. Speller.

J. A. L. Waddell,† M. Am. Soc. C. E. (by letter).—This paper is exceedingly interesting and valuable, for these two reasons: Mr. Waddell.

First.—The author has given to the Engineering Profession in concise form a history and a complete explanation of the phenomenon known as "the fatigue of metals".

Second.—He has shown that, as far as modern bridge designing is concerned, the fatigue of steel is a matter that can, with the utmost propriety, be totally ignored.

Ever since bridge designing began to become truly a science—about a quarter of a century ago—the writer has maintained that the fatigue of metal has no application whatsoever in the proper proportioning of bridge members. Judging from the character of modern bridge specifications, most of the authorities now agree with him; but a few still use formulas which are based, either directly or indirectly, on the fatigue theory; and intelligent laymen are prone to talk about the crystallization of steel in bridges—something which does not exist and never did exist, even in the old days of inadequately proportioned railroad structures. Consequently, it is very gratifying to the writer to see how effectively Mr. Prichard has exposed the fallacy which for many years gave to bridge computers so much extra labor which was totally unnecessary and valueless.

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* This discussion (of the paper by Henry S. Prichard, M. Am. Soc. C. E., published in January, 1916, *Proceedings*, and presented at the meeting of March 1st, 1916), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† Kansas City, Mo.

Mr. Waddell.

For non-reversing stresses, Mr. Prichard points out that, even with wrought iron, under the worst possible circumstances, the actual intensity of working stress must be as great as 30 000 lb. in order to produce any fatigue that will ultimately result in rupture; and as the weakest bridge steel is fully 20% stronger than wrought iron, the corresponding limit for that metal would be 36 000 lb. Now, as modern bridge specifications stress medium-carbon steel up to only 16 000 lb. per sq. in. for the usual loadings when the effect of impact is included, it is evident that the factor of safety is about 2.25. It is true that, when the greatest possible wind-load stresses are combined with the maximum live, impact, and dead-load stresses, it is permissible to stress the metal 30% higher, or to 20 800 lb. per sq. in., which would reduce the factor of safety to 1.73; but this is practically an impossible loading; hence it may be concluded that, as far as fatigue without stress reversal is concerned, modern bridges have a factor of safety of about 2. This is used so as to cover the possibility of small imperfections existing in the metal; and it is an ample allowance for that and all other considerations.

For the case of reversing stresses, however, it is not quite so evident as it is in the case of non-reversing stresses that the effect of fatigue can be entirely ignored; hence a simple computation will be made to prove it.

In the first place, it should be stated that for ordinary bridges the members subjected to alternating stresses are not affected by wind, hence the excess percentage for intensities with wind-load combinations need not be considered. The writer's latest specifications for the effect of reversing stresses provide that when the reversion comes from a single live loading, the sectional area of any piece is to be computed by adding to the maximum tension 75% of the maximum compression and dividing the sum by 16 000; also, by adding to the maximum compression 75% of the maximum tension and dividing the sum by $16\,000 - a\frac{l}{r}$, where a is equal to 60 for riveted construction or 80 for pin-connected construction. In case the reversion is produced by some other live loadings, the same method is to be followed, except that 50% instead of 75% is to be added. The larger of the two areas thus obtained is, of course, the one to be adopted.

The worst case of reversion that can be found in ordinary bridge designing is that of the web diagonal at the foot of the middle vertical post in a very long-span, simple-truss bridge having an even number of double panels. If it is assumed that the live-load tensile stress on the diagonal, including impact, is 700 000 lb., the dead-load tension thereon will be about 100 000 lb., and the live-load compression (including impact) about 570 000 lb.

Proportioning for tension, we have: Mr. Waddell.

$$A = \frac{750\,000 + 100\,000 + 0.75 \times 570\,000}{16\,000} = 76.7 \text{ sq. in.}$$

Adding 20% for rivet-holes makes 92 sq. in.

Proportioning for compression, assuming that $\frac{l}{r} = 50$, and that the truss is pin-connected, we have:

$$A = \frac{570\,000 - 100\,000 + 0.75 \times 700\,000}{12\,000} = 83 \text{ sq. in.}$$

It is seen, therefore, that it is the tension which counts; and, consequently, the maximum actual intensity on the net section will be

$$\frac{700\,000 + 100\,000}{76.7} = 10\,400 \text{ lb., nearly.}$$

The elastic limit for medium bridge steel is 35 000 lb. per sq. in., and, as the worst case of percentage for fatigue of such steel given in Tables 3 and 4 may be taken as not exceeding 60, the safe limit for reversion would be 35 000 × 0.6 = 21 000 lb., or almost exactly twice the actual intensity just found for the most unfavorable condition of stress reversion.

From these rough figures it is safe to conclude that, as far as the old bugbear of fatigue of metal is concerned, modern steel bridges will have a factor of safety of 2 after the effects of impact from live load have been included.

Mr. Prichard's paper certainly ought to put an effective stop to any further talk among engineers concerning fatigue of metal in steel structures, and to expressions of dread from educated laymen about the danger to the traveling public from crystallization of metal in bridges. If such a result is attained, Mr. Prichard will truly deserve the hearty thanks, not only of the Engineering Profession, but also of people in general, for his exhaustive and masterly memoir.

Henry B. Seaman,* M. Am. Soc. C. E. (by letter).—In referring to the use of the Launhardt formula for bridge design, Mr. Prichard states: Mr. Seaman.

"It is not reasonable to apply this and similar formulas to the design of bridges, because two of the fundamental considerations on which such formulas rest are not realized in these structures, * * *."

The writer, however, would call attention to the fact that objections to the use of the Launhardt formula rest on much broader grounds, namely, the formula itself is not justified, either in its manner of

* New York City.

Mr. Seaman. deduction, or in the tests on which it rests. This was discussed fully before the Society in 1899.*

Mr. Turner. C. A. P. Turner,† M. Am. Soc. C. E. (by letter).—This paper again brings up for discussion the maximum and minimum formulas which have largely disappeared from bridge specifications to-day. These formulas are based on the assumption that there is some direct relation between detrimental effects of high and low stresses, some of these stresses being below the so-called elastic limit of the metal. The elastic limit is determined commercially by the drop of the beam; but, in more precise tests, the extensometer is used and the set noted. The degree of elasticity thus determined, however, even when there is no set or deformation, does not determine the true elastic limit, because some of the work applied to the bar in stretching it may not be given back in its return to its original form during removal of the load, so that it would take a very delicate apparatus indeed to determine what is going on within the bar. In general, it is known that every set or permanent distortion is accompanied by heat. It is known that the bar grows colder as it is stretched, until some set takes place.

By delicate thermo-electric means,‡ it is possible to determine what is going on within a bar and how far that bar may be stretched without the evolution of heat accompanying either deformation or disturbance of the internal structure. These limits, as determined approximately by thermo-electric measurement, seem to be the same as those within which Bauschinger concludes that, unless there are flaws, range of stress improves the elasticity, ductility, and tenacity of the specimen. In other words, within this range of true elasticity, there is no such thing as fatigue, which later may be so defined as a change in the structure of the bar brought about by excessive stress. If the viewpoint be in fact that just outlined, then fatigue formulas have no place in the proper design of bridge structures in which the intention is to keep stresses within such well-defined limits that over-strain does not occur. Over-confidence in the logical foundation of maximum and minimum formulas seems to have been responsible, in part at least, for the high stresses allowed in portions of the ill-fated Quebec Bridge. More uniform working stresses, with a slight improvement in the make-up of the sections, would undoubtedly have prevented this unfortunate failure. The acceptance by some of maximum and minimum formulas seems to have arisen, not from the teaching of experience in bridge construction, but rather on account of their

* "The Launhardt Formula, and Railroad Bridge Specifications", *Transactions,* Am. Soc. C. E., Vol. XLI, p. 140.

† Minneapolis, Minn.

‡ *Transactions,* Am. Soc. C. E., Vol. XLVIII, p. 140.

plausibility from an algebraic standpoint and a disregard of any precise distinction between true and approximate values of the elastic limit. Mr. Turner.

T. D. Lynch,* Assoc. M. Am. Soc. C. E. (by letter).—The writer's experience has shown that very few engineers realize how low the true elastic limit really is in untreated or annealed structural steel. Mr. Lynch.

Plates having a tensile strength of more than 60 000 lb. per sq. in. may, and often do, have a true elastic limit of 15 000 lb. per sq. in. or less, and the fact that it has been customary to use a large factor of safety is the only excuse many structures have for not falling.

As engineering progresses toward economical production and designers work to closer and closer limits, it is necessary to study more carefully the real characteristics of the material used.

This has been found to be true in the manufacture of heavy machinery, and structural engineers will find it equally true in making safe their great constructions of bridges and buildings. Those who are working to the "yield point" as taken by the drop of beam will find on final analysis that it means practically nothing unless used as indicative of the material's real value as having been determined by special tests to represent each class of material—untreated, heat-treated, or annealed.

The writer is pleased to refer any member who may wish to examine this subject further to two papers† presented by him before the American Society for Testing Materials.

There seem to be two fundamentals that must not be overlooked, although in many cases research work may be necessary to determine them:

First.—Study stresses to know what they are.

Second.—Study the characteristics of the steel to be used; determine its true elastic limit; and keep below it.

These two fundamentals can but insure safety of construction.

James E. Howard,‡ Esq. (by letter).—Mr. Prichard presents a paper on the physics of iron and steel, which is of exceptional interest; its scope, if amplified, would constitute a treatise on the fundamental properties of structural materials. Mr. Howard.

It can hardly have escaped notice that a tendency has displayed itself recently to overlook some of the basic and underlying features which govern the physical properties of metals; and, in the examination of iron and steel, tests are multiplied, giving them considerable diversity without having scientific ends in view, and not attaining

* Wilkinsburg, Pa.

† "The Use of the Extensometer in Commercial Work", *Proceedings*, Am. Soc. for Testing Materials, Vol. VIII, 1908; and "Elastic Limit", *Loc. cit.*, Vol. XV, Part II, 1915.

‡ Washington, D. C.

Mr. Howard.

results of direct application to the conditions which prevail in the use of constructive materials.

On account of the attention which is given to the principles on which engineering practice in the use of steel should rest, and other reasons which are equally conspicuous, this paper possesses interest of unusual degree.

In the different places in which steels are used, the requirements vary, and metal suitable to meet these varied needs must be regulated according to the demands which are present. The properties of the materials should bear a definite relation to service requirements. This calls for a proper selection of metal in each case and a careful discrimination as to what constitutes the important factors, in order to promote durability under working conditions.

There are limitations in respect to the ability of all grades of steel to endure stresses. Steels of different composition have, in their primitive annealed states, definite limits of endurance, the maximum utilization of which is influenced by the manner in which they are loaded. In an unannealed state, or after having been subjected to heat or mechanical treatment, their properties are materially modified. It is desirable to ascertain the influence which different states of the steel have on its endurance for varying conditions of service. The initial properties easily admit of modification, which the tests of the metal clearly show; nevertheless, it is not always certain what ultimate or permanent advantages accrue from the possession of these modified properties. This information must be acquired through special experimental inquiry or as the result of long exposure under service conditions.

It is desirable to ascertain what features, in the initial properties, are indexical of those which contribute toward final durability.

Establishing the value of the elastic limit is early brought to notice when determining the physical properties of steel. It would seem that very little difficulty should be encountered in agreeing on what constitutes this factor, whether for research or for commercial purposes. Experience with metals has been ample to establish the fact, at least within limits of practical importance, that the modulus of elasticity of steel has a constant value within the limits of over-straining forces, that is, until a decided permanent set has been given the metal.

This being the case, the stress-strain curve is necessarily a straight line up to the load which causes a permanent set. The departure of the curve from a straight line, therefore, must indicate that a permanent set has been given the steel. It does not appear necessary to release the load during testing to confirm such an indication.

In a general way, these remarks comprise the principal statement which need be made in reference to defining the elastic limit of steel. Whether there is or is not a well-defined elastic limit in a given piece

Mr. Howard.

of steel, due to composition or treatment, and what degree of responsibility attaches to the manipulation of the test in obscuring that limit, are matters to be considered, but do not constitute a part of the main question.

Sharpness of definition of the elastic limit depends on the grade of steel, and on its state of initial strain. Concerning initial strains, they are affected by the manipulation of the steel and by incidents connected with its manufacture.

In the milder grades, jogs appear in the stress-strain curves, the metal displaying considerable elongation without increase of load, or under slightly diminished stresses. Jogs also appear when the metal is moderately heated, and disappear when higher temperatures are reached. Reversal of stress, from compression to tension—each being an over-straining load—removes the tendency to display a jog in the curve just beyond the elastic limit. The harder steels do not display jogs.

Initial strains obscure the sharpness of the elastic limit and tend to render its position vague. Initial strains may be acquired by a rapid rate of cooling during manufacture, and may result also from subsequent mechanical treatment, that is, from cold-working. Initial strains will be of two kinds, tension and compression, in order to maintain a state of equilibrium. The magnitude of one or both may at times reach and coincide with the elastic limit in those parts of the bar in which they exist.

An external force required to cause a permanent set will be the difference between the real elastic limit of the steel and the initial strain present which has the same algebraic sign as the external force. If internal initial strains coincide with the elastic limit, then any external force, however small, will cause a permanent set. Initial strains vary in their intensity in different parts of the cross-section of the bar, whence it follows that an external force gradually increased causes a progressive development of permanent sets. Local sets gradually extend to other parts of the cross-section, as external loads are increased, until the metal is in a state of over-strain throughout.

All rolled structural shapes acquire initial strains during fabrication, and these shapes necessarily display early local sets when loaded either by tension or by compression. The influence of such strains is particularly felt in tests on the ultimate strength of compression members. Initial strains, corresponding to many thousand pounds per square inch, residing in the component parts of built-up columns, and not given due consideration, necessarily tend to render futile all efforts to establish formulas for long columns.

Until loads are reached which cause sets to appear, the rate of extension or compression is not affected by the presence of initial

Mr. Howard. strains in the steel. If the working stresses are low, the initial strains will pass unnoticed in structural members. It can hardly be said that the metal has no elastic limit when perchance initial strains exist in such degree that local sets are displayed under the earliest increments of load.

The effects of eccentricity in loading in the testing machine are similar to those caused by initial strains, in respect to the development of early sets. Relative to this matter, a prolific source of error is recognized which attaches to the manipulation of tests. Extensometer readings, of which the following are recent examples, showed measurements on three elements of a test piece, 120° apart, in which the stresses corresponding to the strains reported were 12 000, 15 000, and 18 000 lb. per sq. in., respectively. That is, the strain on one element was one and one-half times that on another. Early and progressive sets must necessarily have been developed on the side of the test piece which was strained so much in excess of that of the shorter side.

The modulus of elasticity is disturbed in over-strained steel, and temporarily has a lower value than normal. Temporarily, at least, it also has a variable value in over-strained steel. The reduction in value, however, is not of so pronounced a degree as to obscure the limit at which permanent sets are first acquired.

A number of terms have been proposed in current technical literature to apply to that portion of the stress-strain curve which is in the vicinity of the elastic limit. It appears that a clear conception is not held concerning the underlying causes which affect this portion of the curve, and efforts directed toward increasing the terminology pertaining thereto seem to confuse rather than clarify the subject matter.

The importance which attaches to the accurate determination of the elastic limit, and the primitive state of the steel, depends somewhat on the uses to which it is to be put. In direct tension, service stresses range from a few thousand pounds up to (or exceeding) 150 000 lb. per sq. in. The latter stress is applied to steel in the form of hard-drawn wire. In most compression members the elastic limit practically fixes the maximum stress which the material will endure and maintain its shape without impairing the integrity of the structure of which the member forms a part.

For the purpose of enduring alternate stresses of tension and compression, the most satisfactory treatment of steel is one of some obscurity. Experience has demonstrated the desirability of limiting the bending loads in such cases to unit stresses of moderate degree. The problem of furnishing a steel of maximum durability for sustaining repeated alternate stresses has hardly been solved. The primitive properties of steel may be made to show decided increase in values by suitable regulation of its chemical composition, and also by heat and mechanical treatment. To establish whether these high, induced values are of permanent advantage is a matter which must be determined by exposure to different conditions of service, long continued. Mr. Howard.

There are certain situations in which complicated conditions exist. Steel rails are exposed to the direct bending stresses of train loads, which cause alternate stresses of tension and compression according to the position of the wheels with reference to given places on the rails, in addition to which there are internal strains at the top of the head and on the gauge side, due to the cold-rolling action of the wheels, and these strains augment cooling strains which are introduced in the rails in the process of manufacture.

The influence of primitive toughness in the metal and its advantages in steels when exposed to a large number of repeated alternate stresses of moderate degree is not apparent. Under such conditions all grades of steel may be ruptured without the display of appreciable elongation or contraction of area. Toughness of the metal is available for a time in resisting deforming loads, but its display is not witnessed in cases of repeated stresses, long continued. Some evidence exists which attaches importance to the tensile strength of the steel under these circumstances. Steels exposed to repeated alternate stresses at a blue heat have shown greater endurance than when tested cold. This increase in endurance takes place in the zone of temperature in which the tensile strength of the metal is much above that at atmospheric temperatures. In relation to this matter it should be remarked that the elastic limit is then somewhat lower than at ordinary temperatures of testing.

Slip bands in the micro-structure of steel have been pointed out as precursors to or attendant phenomena to rupture by repeated stresses. Microscopic examination has not in some cases furnished detectable changes in structure. In shafts which were ruptured by repeated stresses which strained the steel by amounts not exceeding one and one-third thousandths of an inch per inch, that is, up to 40 000 lb. per sq. in. fiber stress, rupture being reached after 150 000 000 repetitions, no observable change in structure was revealed. Still, it does not appear unlikely that manifestations of a macroscopic and microscopic order, witnessed in cases of pronounced deformation, may in kind be similar to those more minute changes which attend the rupture of steel under long-continued stresses of moderate degree. It would greatly aid in the matter of choosing the most suitable composition and treatment of steels if the phases through which rupture was reached were better known. It is a matter of no little regret that the research laboratories of America are not engaged in advance inquiry on these fundamental features which offer so much encouragement in their study.

Mr. Howard. In closing it may be remarked that Poisson's ratio, as found in tests conducted at the Watertown Arsenal, furnished a value for steel between one-third and one-fourth; to be more exact, the value appeared to be almost midway between these fractions.

Mr. Moore. H. F. MOORE,* ESQ. (by letter).—This paper is an excellent discussion of the general action of iron and steel under stress, and should serve to place proper emphasis on the study of the physical behavior of the material in structures.

Mr. Prichard advocates the use of the term "elastic limit" to define the limit of proportionality of stress to strain. Some standard use for this term is highly desirable. At present "elastic limit" is used by some engineers to indicate the limit of proportionality of stress to strain, by other engineers to indicate the yield point of material, and by still others to indicate the stress at which permanent deformation of the material first appears. The last-named use of the term is recommended in the tentative standards of the American Society for Testing Materials, and is followed by most foreign writers. Some standard nomenclature is highly desirable, and though, for static conditions, the limit of proportionality could well be called the elastic limit, for conditions involving fatigue under repeated loads "permanent set" seems more significant than deviation from Hooke's law.

The writer believes that it is doubtful if the elasticity and proportionality of steel are perfect under any conditions, and would refer to the conclusions of Professor E. R. Hedrick, of the University of Missouri.†

Mr. Prichard quotes the test results of Hancock as a proof of the maximum shear theory for the failure of ductile materials. If the maximum shear theory holds for all conditions, the shearing strength of a material must be not greater than one-half the tensile or the compressive strength. Hancock's tests showed that, in general, the shearing strength of steel was greater than one-half the tensile strength, and the agreement of his "elliptical" formula with test results furnishes an empirical relation for various combinations of shearing stress with direct stress, rather than a confirmation of the maximum shear theory. Recent test results by Dr. Becker‡ indicate that for combined stress, in which the shearing stress is relatively low, the strain in steel is the determining factor for strength, and that, for steel, if the shearing stress is more than about 0.6 of the direct stress, the shearing stress governs. Dr. Becker shows that the results of Guest, Scoble, Hancock, and Mason, as well as those of his own tests

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* Professor of Eng. Materials, Univ. of Illinois, Urbana, Ill.

† "A Generalized Form of Hooke's Law", *Engineering News*, Vol. 74, p. 542, September 16th, 1915.

‡ Embodied in a *Bulletin* of the University of Illinois Engineering Experiment Station now in press.

are in better accord with this dual law of strength than with any single law proposed for combined stress. Relative to this matter, the results of Matsumura and Hamabe* for cast iron are of interest. The results of their tests indicate that for cast iron the maximum strain theory holds. Mr. Moore.

The writer agrees with Mr. Prichard's conclusions as to fatigue of materials, but wishes to emphasize certain phases of fatigue phenomena. Attention is called to his statement: "There is nothing in experience or tests to cause fear of such a result [fatigue failure] when the material is of good quality and the stresses are not reversed". This is probably true for structural members for which the repetitions of stress number but a few million, but it would not necessarily be true for machine members in which the numbers of repetitions may number hundreds of millions.

The writer heartily agrees with the author's statement:

"Although experiments do not warrant the conclusion that steel and wrought iron can resist endless repetitions of stress to those limits [two-thirds of the statically determined elastic limit], neither do they warrant the conclusion that these metals cannot do so."

If experiments do not prove conclusively that materials can resist an infinite number of repetitions of stress, it would seem that safe practice would dictate methods of computation for fatigue based on the supposition that destructive effects similar to those set up under high stress are set up with diminished intensity under low stress, and that it should be recognized that structures which could resist a few million repetitions of a given stress might fail under billions of repetitions of the same stress. This does not in any way call in question the author's statement:

"* * * both experiments and experience indicate that steel and wrought iron in bridges can resist to these limits for so long a period that the resistance may for practical purposes be considered permanent."

For the busiest bridges, the number of repetitions in a normal "lifetime" for the bridge amounts to a million or two, and in most members the stress is not reversed. In other words, the criterion of static strength governs the design of bridges and buildings, rather than the criterion of fatigue strength. For machine members, and for structural members carrying reversed stress, the fatigue strength would be the governing factor in many cases.

Professor Basquin, of Northwestern University, has pointed out†

* *Memoirs* of the College of Engineering, Kyoto Imperial University, February, 1915.

† "The Exponential Law of Endurance Tests", *Proceedings*, Am. Soc. for Testing Materials, Vol. X, 1910, p. 625.

Mr. Moore. that, for a considerable range of stress, the results of repeated stress tests of metals are well represented by an exponential equation:

$$S = \frac{C}{R^n}, \text{ or } \log.\ S = \log.\ C - n \log.\ R, \text{ in which}$$

S = fiber stress necessary to cause failure;
R = number of repetitions of stress necessary to cause failure; and
C and n are experimentally determined constants.

For the past year Mr. F. B. Seely, of the University of Illinois, and the writer have been engaged in an investigation of test data for repeated stress tests. Some tests have been made in the University of Illinois Materials Testing Laboratory, and data of other tests have been studied. As a result of this investigation the following modification of Basquin's formula is proposed:

$$S = \frac{B}{(1 - Q)\, n^{0.125}},$$

or $\log.\ S = \log.\ B - \log.\ (1 - Q) - 0.125 \log.\ N$, in which

S = fiber stress necessary to cause failure;
N = corresponding number of repetitions of stress (the "life" of the piece);
Q = ratio of minimum stress applied to maximum stress ($Q = 0$ for load varying from zero to a maximum, $Q = -1.0$ for a completely reversed load);

B is an experimentally determined constant, approximate values of which are given in Table 5.

TABLE 5.

Material.	Value of *B*.
Structural steel and wrought iron	250 000
Steel, 0.45% carbon	350 000
Cold-rolled steel shafting	400 000
Tempered spring steel	600 000 to 800 000

It may be noted that these values are larger than those given by Mr. Seely and the writer in their paper before the 1915 meeting of the American Society for Testing Materials; the values in Table 5 are given as a revision of the earlier ones, and, in the opinion of Mr. Seely and the writer, are more reliable. An error in the method of deducing the value of B from test data has been corrected.

If the foregoing formula is applied to the determination of stresses in structural members for which the stress is not reversed (for structures, N is rarely more than 1 000 000 or 2 000 000 in the life of the structure), the value of S to cause fatigue failure, in practically all cases, will be found to be greater than the yield point strength of the material; hence static strength governs the design. This is in accord with the conclusions reached by Mr. Prichard. If, however, the stresses in machine members are investigated or those in oft-stressed structural members in which the stress is reversed, fatigue strength, in most cases, will be found to govern the design. Mr. Moore.

Different criteria of strength govern static strength and fatigue strength, respectively, and in the design of any structure or machine both static strength and fatigue strength should be considered.

F. N. SPELLER, ESQ.* (by letter).—In reference to the last paragraph on page 80† of this paper, it is not often that the irregularities in elasticity of steel are referred to in papers of this kind. It is well known to most of those who are engaged in the physical testing of steel products that the true elastic limit of the metal is usually not developed on the first application of stress. A slight permanent set is generally found far below the true elastic limit. This seems to indicate that the stress on first loading is not always taken up equally by the grains and that there is, so to speak, some granular slack which must be taken in and the structure adjusted to the load until the stress is equally distributed in the section. The cause of this phenomenon is probably to be found in the irregular size and shape of the crystalline grains which constitute the normal structure of all metals. On the effect of straining of metals, Professor Sauveur makes the following suggestive statement‡: Mr. Speller.

"It is seen that, contrary to the general belief, the metals remain crystalline after the severest strain, and that the flow or plastic strain in metals is not a homogeneous shear such as occurs in the flow of viscous fluids, but is the result of a limited number of separate slips, the crystalline elements themselves undergoing no deformation."

The necessity for the adjustment of the structure of the metal by a preliminary stress applied below the elastic limit is recognized in some of the more modern specifications. For example, The Interstate Commerce Commission's "Shipping Container Specifications No. 3", for high-pressure cylinders, contains the following clause:

"Each finished and annealed cylinder must be subjected to a hydrostatic test of not less than 3 000 lb. per sq. in. in a water jacket, or other apparatus of suitable form, to furnish reliable data. The permanent volumetric expansion must not exceed 10% of the whole volumetric expansion at this pressure."

In "Specification No. 4" of the Interstate Commerce Commission (ammonia cylinders) a pressure of 800 lb. preceding the official test of 1 000 lb. is permitted. It would be better, in the writer's opinion, to make this preliminary test at a pressure more nearly approaching, but not exceeding, the official test.

* Metallurgical Engr., National Tube Co., Pittsburgh, Pa.

† *Proceedings*, Am. Soc. C. E., for January, 1916.

‡ "The Metallography and Heat Treatment of Iron and Steel", 1916 ed., p. 93.

Mr. Speller.

The physical properties of steel are also temporarily altered by the mechanical machining of test pieces. It has become common practice to allow test pieces to "rest" for a day or two before pulling, in order to develop the true elongation and elastic limit. An increase of 2% elongation in 8 in. may be obtained after eliminating surface strains by this "rest cure", which is simply a form of slow annealing.

AMERICAN SOCIETY OF CIVIL ENGINEERS

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PAPERS AND DISCUSSIONS

DISCUSSION ON FLOODS AND FLOOD PREVENTION*

BY MESSRS. H. M. EAKIN AND JOHN W. HILL.

H. M. EAKIN,† ESQ. (by letter).—The Progress Report of the Special Committee on Floods and Flood Prevention is a distinct disappointment to one interested in the general progress of applied science, who had expected the deliberations of the Committee to result in a constructive policy which would be clear of the inconclusive controversy that has heretofore hindered adequate progress in river improvement, and would, therefore, merit the endorsement of the Society and gain an effectively general support. Essentially, the report is an endorsement of specific projects of river improvement which are the subject of disagreement among scientists and engineers of standing. It also carries implications and statements that are not entirely sound. Mr. Eakin.

The general spirit of the report implies that there exists an adequate, esoteric if not general, understanding of the scientific principles involved in river treatment, and that there is consequently only the need for such investigations as will furnish additional and standardized data as to the environment of their operation. The Committee evaluates with implied authority the relative merits of the various suggested methods of control, and shows its allegiance to current projects in statements that are not supported by fundamental scientific analysis.

The value of this implied authority may be indicated somewhat by an examination of the last paragraph under (*e*) page 2779.‡ It is indirectly stated that the use of levees effects an increased channel storage that induces a lowering of flood levels. This is clearly im-

* This is a discussion on the Progress Report of the Special Committee on Floods and Flood Prevention for 1915, presented to the Annual Meeting, January 19th, 1916.

† Washington, D. C.

‡ *Proceedings*, Am. Soc. C. E., for December, 1915.

Mr. Eakin. possible, since the channel storage given by levees is largely in space above the level which the same flood waters would assume if allowed to spread unhindered over the flood plain. Moreover, the confinement of floods between levees increases the facility of flow, so that discharge to successive reaches is progressively augmented above the normal as the effects of elimination of normal flood plain storage accumulate, and flood heights are correspondingly above the normal all the way to the sea. The increased flood height in the improved reach lowers the surface gradient for some distance up stream, decreasing velocities, and correspondingly increasing flood heights. The statement that levees reduce flood heights by increasing channel storage is obviously fallacious, yet it is advanced in the report as an important principle, generally overlooked, but fortunately recognized by the Committee.

The report fails of a much needed mission in not presenting clearly the present status of the science of streams. It does not indicate the scientific uncertainty as to the laws that underlie the basic problems of stream control, the reciprocal variability of discharge, grade, competence, capacity, load, torsional flow, the development, migration, and elimination of meanders, drainage distances, assortment of débris and extra-channel deposition—in short, the reciprocally determinative relation of erosional processes and physiographic forms, and the possibilities of selective artificial mutation and control of all these factors.

The problems of stream control reach out into many different branches of science—geology, physiography, meteorology, hydrology, agriculture, forestry, and engineering—and involve abstruse laws outside the scope of these special branches, and as yet imperfectly developed or only vaguely indicated. No individual or organization has as yet commanded such proficiency in all these sciences as to enable them to outline a programme of river treatment with dependable authority. Programmes such as have been outlined from the standpoint of a single science or profession have uniformly failed to withstand scientific scrutiny from other viewpoints. The result has been controversy, partisanship, and effectual inhibition of adequate progress toward the goal at which all honestly are aiming.

Progress of applied science demands, first of all, a dependable scientific authority. As regards stream control, we are apparently without such a basis. The Society probably could perform no greater service to the Profession and to the cause of river improvement and flood control than to devise a means of supplying this lack. The obvious recommendation is that a special organization be created with a personnel made up of variously trained scientists and engineers capable of assembling the pertinent matter of other sciences and of developing by appropriate researches an adequate, specific science of streams. The sound development of the science is prerequisite to its application. Only some such means as suggested can lift the matter of river improvement above the field of speculation and controversy, and make any considerable advance toward adequate achievement. Mr. Eakin.

John W. Hill,* M. Am. Soc. C. E. (by letter).—The frequency of disastrous floods in the Central and Western States during the past 12 or 13 years has directed serious attention to a condition affecting life and property which can no longer be tolerated. The periodical floods in the Mississippi and some other navigable rivers can usually be forecast as to time and river stage, and preparations can be made to discount more or less the resulting property damage; these floods or river rises are seldom attended by loss of life. There is no human foresight, however, which can predict the time of floods in the smaller non-navigable streams of the Middle West and western parts of the country, and it is with these that we are at present most concerned. Mr. Hill.

Floods in the large rivers of the Mississippi Basin are expected every year, although these are not always attended by great property loss or serious interference with business or transportation. Of course, there are no known means of preventing such floods. Rain and snow are bound to fall on the water-sheds, and the waters must flow away through the streams to the great reservoir in the ocean, to be caught up again into the clouds by evaporation, to make more rain and snow at a later date, and repeat the operation of precipitation, run-off, and stream flow, with frequent floods in the larger streams.

Measures to mitigate the destructive influence of great floods in the Mississippi River have been inaugurated and maintained by the States subject to damage, and by the Federal Government, Federal aid being given in the interest of navigation only.

A discussion of floods in the larger navigable rivers would have little bearing on the problem of flood prevention in the valleys of the smaller streams, and, in view of the appalling losses of life and property which have occurred from these in Ohio, Indiana, Kansas, California, and some other Central and Western States in recent years, the people directly affected by the floods have been compelled to insist on a remedy for an intolerable condition. One remedy would be to remove all habitations and perishable property permanently above the flood-plain; but this is not to be thought of as long as other avenues of escape from flood calamities are open. The vested interests in public and private property now lying below the flood-plain represent hundreds of millions of dollars in the States mentioned, and these must be preserved and protected, if individual property rights in these river valleys are to survive.

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* Cincinnati, Ohio.

Mr. Hill.

The frequency of destructive floods in the valleys of the smaller rivers and streams is often under-rated. Thus, in the Great Miami Valley in Ohio, instead of two or three great floods occurring within a century (a statement frequently made), at least five such floods have occurred within 110 years, namely in 1805, 1847, 1866, 1898, and 1913, the first and last dates marking the greatest floods.

Three of these floods have occurred within the writer's recollection. In 1866, while living in Dayton, Ohio, he saw the Miami River out of its banks and flowing several feet deep through the principal streets of that city. Marks made after the flood of 1913 indicated that, on Ludlow Street, south of Fifth Street, the flood of 1913 was about 5 or 6 ft. higher than that of 1866. In 1866, however, the city was much more open—with respect to bridges, buildings, and other obstructions—to the flow of water in the river channel and through the town, and the flood of discharge for 1913 was not as much greater than that for 1866 as might be inferred from the difference in flood heights.

In 1866, Dayton had a population of 30 000, and had much unoccupied territory which is now solidly built up; no pretentious structures had then been erected anywhere within the city limits; the river banks were not lined with dwellings or other buildings; and, when the river rose above the levees, the water found a reasonably unobstructed channel on the lowlands behind the levees on both sides of the river.

Prior to the flood of 1913, the river banks had been pre-empted and built on up to the levees, with a street or boulevard between; several reinforced concrete arch bridges with restricted waterways had been erected in the river channel, and, in many ways, the free flow of an overcharged river had been so much obstructed that the flood discharge of 1866 would have produced higher levels in the city streets had it occurred in 1913.

The flood of March, 1805, is well recorded for the locality of Hamilton, 35 miles from the mouth of the Miami River, by a local historian,* and this flood, in that early day, with no bridges across the river, an unobstructed channel, and few improvements of any kind on the river banks, reached a height as great as that of 1913. It is probable that the dense growth of timber and shrubbery along the river banks and on the bottom lands had some influence in impeding the free flow of the river and raising flood levels; and the existing "standing timber", or forests, may have had some further influence in retarding the run-off toward the stream. If these two conditions are supposed to have balanced, then it would seem that the run-off and stream discharge of the flood of 1805 may have been even larger in the vicinity of Hamilton than in the flood of 1913.

* Mr. James T. McBride, 1831.

Mr. Hill.

The recurrence of great floods in all streams can be surely expected, and the subject of the report of the Committee is the remedies to be sought to prevent future disasters from this source of danger.

The writer is in accord with the views expressed by Col. Townsend in a paper* read at St. Louis, Mo., in April, 1913, on the limited effect of storage reservoirs at head-waters on floods in the Ohio and Mississippi Rivers at Cairo, owing to the relatively small drainage area which such reservoirs can successfully control; and, as has often been stated, if such reservoirs should happen to be full, coincident with a great rainfall and run-off—which is a reasonable supposition during the latter part of the winter—it is difficult to conceive that they have any beneficial influence on the stream flow below, with the whole of the run-off from the controlled water-shed flowing over the spillways and into the discharge channels below the dams. The storage of great volumes of water from the higher portions of a water-shed simply for flood control can scarcely be looked on with favor. The use of the stored water for power, for regulation of stream flow, for irrigation, or for public or industrial water supply, would be sought and probably obtained after the construction of the reservoirs, if it had not been made a feature of the original enterprise. Unless the reservoirs were kept empty before a period of great or long-continued precipitation on the water-shed, they would fail to conserve and restrain the run-off for which they were planned; and, if kept empty in anticipation of heavy downpours, they would be useless for any other purpose than flood control.

The method pursued in Europe—to allow a certain depth at the top of the reservoir for flood control—is practicable, but, in all such instances, the water stored below the flood-plain is applied to some utilitarian purpose—water supply, power, etc. The writer does not recall any investigations showing the control of flood flow below the reservoirs accomplished by this method.

The considerable number of great reservoirs in Germany and France (as far as the writer is aware) have not been constructed only to prevent floods; they have been created for other and more sordid objects. Neither have any of the great reservoirs in India and the United States been built with flood control as the only object in view.

Concerning the influence of forests and reforestation on run-off and stream flow, during periods of heavy or continuous precipitation, the flood of March, 1805, in the Miami River, at Hamilton, is probably as great as any on record for that stream. At that date, the Miami Valley was largely a wilderness, with "standing timber" everywhere on the drainage area, except in the small clearings of the pioneers, and, therefore, one of two propositions must be accepted: either the

* "Flood Control of the Mississippi River," National Drainage Congress.

Mr. Hill. rainfall exceeded that recorded for March 23d to 26th, 1913, or the forests had small or no retarding effect on the run-off.

No record of the rainfall for the 1805 flood is obtainable, and probably there was none, but the time of year and the height of the flood suggest conditions similar to those of March, 1913, when the rain fell continuously for 4 days, the ground and all vegetation was saturated, and a time was reached during the storm when the water was flowing off the water-shed at the same rate as it was falling from the clouds; and if, in 1805, the snow and ice were added to the precipitation, probably the run-off was greater than the rainfall.

The lack of rainfall records and data as to snow and ice conditions makes it impossible to analyze the 1805 flood; but, if the virgin forests did at that time retard the run-off and restrain the stream flow, then the rainfall was probably greater than any on record on this water-shed, and it is reasonable to suppose that it will be repeated in the future. No bridges spanned the Miami in 1805, nor were there any other artificial obstructions in the channel. River crossings were made at fords, by boats, or by swimming, according to the necessities and convenience of the pioneers.

The forests doubtless have some retarding effect on run-off, up to the point of saturation of the trees, undergrowth, and shrubbery, and of the litter and humus on the forest floor. After this point has been reached, the soil in the forest is like that in the clearings, and, as all great floods follow long-continued or very heavy downpours, it would seem that, during the storm, the time must arrive when the retarding effect of the forest is nil.

In Ohio, Indiana, and Illinois there is very little "standing timber", the water-sheds of the streams are denuded, and, after saturation of the ground, the rainfall and run-off should be nearly, if not quite, equal. The retarding influence of ponds and pools on uneven ground, formed during storms, should not be neglected, but their effect on run-off and stream flow, after all, will be small.

The proposition of reforestation with a view to flood control in the large navigable streams may be practicable for the bare lands of the West, large areas of which are not under cultivation but are used only for grazing purposes; but it will be impracticable for the valuable agricultural lands in the valleys of rivers in the Central States. It is scarcely conceivable that a farmer will give up his land to reforestation for flood control, waiting 40 to 50 years until the growing timber on it becomes valuable, and meanwhile deriving very little or no return from the land; nor is it likely that any conservancy district could afford to purchase such lands and reforest them for this purpose. In any event, it is obvious that it would be many years before such reforesting could have much influence on the rate of run-off to the streams.

The writer agrees with Mr. Grunsky that cut-offs are sometimes advantageous, perhaps not in soil like that of the Mississippi channel below Cairo; but, when made in glacial drift formation, experience has shown that they will wear and accomplish good results in flood discharge. Assuming the natural materials of the river channel to be suitable for the maintenance of permanent cut-offs, there can be no doubt that, in a certain instance, where a river, along its meanders from its mouth to its head-waters, is now 170 miles long, and can be shortened by cut-offs to 130 miles, that, with the new slope and increased velocity, the flood-plain will be materially lowered everywhere in its length. Mr. Hill.

Where the bends of a river embrace a populous city, a cut-off would be prohibitive by reason of cost, and perhaps for other reasons, but through farm lands and outside built-up city limits, it can be adopted with advantage. Where the dredged material can be used in levees, the cost of cut-offs will not be prohibitive. Some cut-offs may require training walls, or spur dams, in order to maintain the alignment of the channel, and the materials for these can often be found on the ground.

With the materials before it from which to draw, it is to be regretted that the method of "flood prevention" by so-called "detention" or "dry" reservoirs has not been more fully developed. The literature available to the writer shows few of such reservoirs, and none quite recent in date of construction, if the work now under way on the water-shed of the Little River in the southeastern part of Missouri, and a few reservoirs in prospect,* may be excepted.

Suppose a water-shed, having 75% of its area embraced in the drainage area of the small tributaries, generally of steeper slope than the rivers they feed, with channels often narrow and comparatively deep, often with rocky beds and conditions generally favoring the easy construction of check dams or barriers, and where the valley next to the river, as a rule, is wide and flat, and thoroughly developed, with many populous and prosperous cities and towns along the stream, the river very crooked, with the channel running through a drift formation ranging from builders' sand to large boulders, where cut-offs can frequently be made to straighten and shorten the channel, the stability of cut-offs and diversion channels in this instance having been proven by a test of more than 60 years: Is not this an instance where the retardation of flow—or, if desired, storage of water for flood protection—should be in the narrow valleys and ravines of the smaller tributaries, rather than in the main valley; and is not this also an instance where channel improvement will apply?

* Briefly mentioned in Appendix 5, of the "Report of the Pittsburgh Flood Commission".

MEMOIRS OF DECEASED MEMBERS

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

EDMUND JOB STEERE, M. Am. Soc. C. E.*

DIED JULY 18TH, 1914.

Edmund Job Steere was born in Providence, R. I., on June 13th, 1874. He studied Civil Engineering at Brown University, from which he was graduated in 1894 with the degree of Ph.B.

During the summer vacations of 1891, 1892, and 1893, Mr. Steere was employed in the office of the City Engineer of Providence, mostly on highway work. After his graduation in 1894, he was appointed First Assistant to the Resident Engineer on the construction of the Red Bridge over the Seekonk River, in Providence, and, in 1895, he served as Resident Engineer during the construction of the Exchange Bridge over the Providence River. From 1896 to 1898, he was engaged, as Resident Engineer, on the construction of stone arch bridges in Roger Williams Park and in Davis Park, in Providence. In 1898, he was employed as Engineer on the building of retaining walls along the Providence River and also on the Weybosset Bridge over that river. In 1899, he was appointed City Inspector of underground electric and telephone conduits for the City of Providence, which position he retained until 1901.

In 1901, Mr. Steere was employed as Civil Engineer by the J. W. Bishop Company, General Contractors, on the Lonsdale Bleachery. In 1902, he was made Construction Engineer and put in charge of the construction of the power-house and 1 800-ft. dam at Danville, Va. In 1904, he was made Superintendent of Construction and had charge, for his Company, of the construction of mills, power-houses, dams, and bridges, in various parts of the United States.

From 1906 to 1909, Mr. Steere was engaged as Superintendent of Construction and Contractors' Engineer on the construction of Post Headquarters Building, and several small buildings, at the United States Military Academy, West Point, N. Y. He had full charge of this work which was valued at $500 000.

After the completion of his work at West Point, Mr. Steere was offered a position on the Panama Canal and had offers from contracting firms of national repute from all over the United States. He refused them, however, to become, in 1909, Chief Engineer and General Super-

* Memoir prepared by the Secretary from information furnished by Henry W. Ballou, Assoc. M. Am. Soc. C. E., and on file at the Society House.

intendent of the J. W. Bishop Company. In this position he had charge of the design and construction of mills in Rhode Island, Massachusetts, and Connecticut; sewerage systems for New Bedford, Mass., and Providence, R. I.; a pipe line in Warren, R. I.; power-houses at Danielson, Mechanicsville, Ashton, Milton, etc.; and business blocks in Providence and New Bedford. He had charge of from thirty to forty construction jobs a year, averaging in value from $1 000 000 to $2 000 000.

In 1914, Mr. Steere was appointed the first Commissioner of Public Buildings under the City Government of Providence, R. I., which position he held at the time of his death which occurred from drowning, on July 18th, 1914, in an attempt to save the life of a friend.

Mr. Steere was a man of few words, one whose instinct was to listen, to think, to act, and to give orders quietly. Of great physical strength, he was deliberate and almost slow in his bodily movements, except in moments of emergency when he revealed a body and muscles worthy of a tiger. An idea of his capacity for work may be had from the fact that he had directed millions of dollars worth of construction before he was forty years old, and often drove his automobile from 150 to 200 miles per day, superintending the work of 1 200 men on from six to ten jobs scattered over Rhode Island and adjoining parts of Massachusetts and Connecticut.

Mr. Steere was a typical Yankee in that he always answered a question by asking another, and his statements were made preferably in an interrogative form. He was ill at ease if in any way conspicuous, and although he had many acquaintances, his intimate friends were few. He was devoted to his family and denied himself to his friends in order to spend the time with his two sons who survive him.

Mr. Steere was elected a Member of the American Society of Civil Engineers on October 1st, 1913.

STEVENSON TOWLE, M. Am. Soc. C. E.*

DIED FEBRUARY 14TH, 1916.

Stevenson Towle, the son of Jeremiah and Jane (Abeel) Towle, was born in New York City, on July 29th, 1837. In 1822, Jeremiah Towle had removed from New Hampshire to New York City where he became prominent in municipal affairs. He selected and planned the present water supply, served as Commissioner of Charities and Schools for many years, and was mainly instrumental in the establishment of the present park and ward school systems of the City.

* Memoir prepared by the Secretary from information furnished by Charles S. Towle, Esq., New York City.

Stevenson Towle was educated in the public schools of New York City, having been among the pupils first registered in the First Ward School. He continued his studies at the Free Academy, now the College of the City of New York, from which he was graduated.

Having studied Civil Engineering, Mr. Towle was made City Surveyor of New York in 1857, and, in 1860, the Mayor appointed him to visit and examine the sewerage systems of European cities for the purpose of obtaining the information on which the present sewer laws of the city are based.

From 1870 to 1886, Mr. Towle was Chief Engineer of the Department of Sewers of New York City. In addition to this work he also, in 1871, served, with Generals McClellan and Franklin, on a Commission appointed to lay out Long Island City; and, in 1883, he planned and built the first cable railroad (Tenth Avenue) in New York City.

In 1886, Mr. Towle became Consulting Engineer for the Broadway Arcade Rapid Transit Railroad, and, in 1887, he was appointed by Mayor Hewitt as a member of the first Rapid Transit Commission. In the same year he visited Europe, by appointment of Mayor Hewitt, and investigated the question of improved pavements throughout the various cities.

In 1888, Mr. Towle was made Park Commissioner of New York City, and, in 1889, was appointed Consulting Engineer for the Department of Public Works, in special charge of improved street pavements. He held this position until April, 1897, during which time he introduced a system which is now extensively used throughout the United States.

In April, 1897, he was appointed Consulting Engineer of the Sewer Department in connection with the construction of the Rapid Transit Tunnel. In 1902, Mr. Towle had a stroke of apoplexy, which left him subject to heart disease, and it was an attack of this trouble that caused his sudden death at his home, the Brevoort Farm, at Mamaroneck, N. Y., on February 14th, 1916.

Mr. Towle was an extensive traveler, and had made investigations on subjects pertaining to his Profession on all the Continents. He was engaged on many of New York's transportation and sanitation projects. He was a Director of the Institute of the Deaf and Dumb and a Member of the Scotch-Irish Society.

He was married on October 12th, 1863, in New York City, to Mary Stewart, daughter of Henry and Jane (Stewart) Brevoort, who was a member of one of the oldest Knickerbocker families of that city. He is survived by three sons and five daughters.

Mr. Towle was elected a Member of the American Society of Civil Engineers on February 19th, 1868, and served the Society as Director during 1887 and 1888.

WALTER COX BOWEN, Jun. Am. Soc. C. E.*

Died May 8th, 1915.

Walter Cox Bowen was born at Shiloh, N. J., on November 17th, 1886. He received his elementary education in the public schools of Shiloh, and, after his graduation from the High School, taught school in Southern New Jersey for several years, prior to entering college.

Mr. Bowen began his professional life in 1908, when he entered Rutgers College as a student in Civil Engineering. During the four years he attended college, he spent his summer vacations in the field on various engineering projects.

After his graduation in 1912, Mr. Bowen entered the engineering offices of Clyde Potts, M. Am. Soc. C. E., as Assistant Engineer, where he remained until his death. While he was in charge of the construction of sewage and water works for Milltown, N. J., a suburb of New Brunswick, he took post-graduate work in chemistry and bacteriology at Rutgers College, in order to prepare himself for his chosen profession in sanitary engineering.

He died on May 8th, 1915, as a result of injuries received in an explosion in a sewage plant at Ocean Grove, N. J.

While at college Mr. Bowen took a very active part in athletics and social life, and was a member of Delta Kappa Epsilon Fraternity. In his Senior Year he was Manager of the football team, Captain of the baseball team, Captain of one of the companies in the Cadet Corps, and President of the Civil Engineering Club. He also belonged to the Masonic Fraternity.

Nothing more apt could be said at this time than to quote the closing words of the sermon delivered by President Demarest, of Rutgers College, at the funeral services in Shiloh, on May 11th, 1915, who stated:

"I must say a word of personal appreciation touching him who has gone from us. I thought a great deal of him. I had come to know him well, as the Professor may come to know the student, as a President of the College may come to know an undergraduate.

"I speak as the one who presides over the College, but also for the class to which he belonged, for the fraternity of which he was a member, for the various organizations of which he was a part, and for the associates with whom he was just now establishing himself in his life work.

"Death coming so suddenly, so unexpectedly, and indeed in so tragic a way, one taken away in the days of his youth, our souls are sorely tried; it seems so premature. Yet, on the other hand, we think of the eternal youth of one going out of this life on into richer life in the prime of his strength, still to do God's will.

* Memoir prepared by F. E. Caldwell, Assoc. M. Am. Soc. C. E.

"I think of this young man so. He was a man, and he was manly. He was reliable, so true and steadfast. He could be sought for a word of good judgment, and he could be sought for a word of intelligent sympathy. He was the sort to become a leader among his fellows, a worker in all good ways of college life. He was the sort to become a leaven in a community of young men, leavening the life of young men with the spirit of devotion.

"I went again and again to him to get the point of view of the student, and never failed to get good judgment, or to find the viewpoint that could realize the other viewpoint, so bringing the best issue.

"It is a fine thing to leave a record like that."

Mr. Bowen's professional career was brief; he was taken in the fullness of his youth, leaving behind the memory of an earnest life, well spent.

Mr. Bowen was elected a Junior of the American Society of Civil Engineers on December 31st, 1913.

EDWARD WOOLSEY COIT, F. Am. Soc. C. E.*

DIED SEPTEMBER 25TH, 1915.

Edward Woolsey Coit was born on July 27th. 1837, at Plattsburg, N. Y., at which place his father was the Rector of the Protestant Episcopal Church. He was one of six sons, only one of whom, Dr. J. Milnor Coit, of Munich, Germany, now survives. An elder brother, the Rev. Dr. Henry A. Coit, was the well-known and much loved Founder and first Headmaster of St. Paul's School, at Concord, N. H. The only academic education Mr. Coit had was that received in his own home, his father having been his instructor.

Mr. Coit began his business careèr as clerk in a store dealing in general merchandise in Champlain, N. Y. After a residence of about one year at that place he accepted an offer to enter the employ of Morris, Tasker and Company, of Philadelphia, Pa. He remained with that firm all through the period of the Civil War and until 1877, when he resigned to become General Manager of the Reading Iron Works, at Philadelphia, of which Company Mr. John Penn Brock was President at that time. After serving for five years as General Manager, Mr. Coit was elected President of the Company, Mr. Brock having resigned.

In 1892, Mr. Coit became General Manager of the Lake Superior Iron Ore Company, and three years later he moved to St. Louis, Mo., to become Manager of the Branch Works of the National Tube Company in that city. He remained with this Company until 1902,

* Memoir prepared by Frederick H. Post, Esq., Topanga, Cal.

when he moved with his family to California, making his home in Los Angeles.

After a couple of years of much needed rest, Mr. Coit again entered the business world. He became a member of the official staff of the R. H. Herron Oil Wells Supply Company, affiliated with the Oil Wells Supply Company of Pittsburgh, Pa., and remained actively engaged in the affairs of the Company until the day preceding his sudden death on September 25th, 1915.

Mr. Coit was regarded with the highest esteem in both the business and social world. During his long business career he was intimately associated with many of the prominent men of his day, and among his friends and social intimates were Mr. James B. Gowan, a former President of the Philadelphia and Reading Railroad, the late George F. Baer, also a former President of the same road, Messrs. John Penn Brock, Joshua Rhodes, R. T. Crane, and many others. One who knew Mr. Coit most intimately writes as follows concerning his reputation as a man of affairs:

"His reputation was second to none in the iron business, particularly in the manufacture of iron pipe and kindred products. He was an authority whose advice was sought by men of all ranks in that line of business."

The same writer says of his relations to others with whom he came in business contact:

"He believed in giving every man a chance, and advocated fair play in all the various phases of business. He was charitable, believed in young men, and pushed forward a host of them. He had the happy faculty of bringing out the best in men."

Mr. Coit took an interest in every good work, and to many he gave with a liberal hand. If it was possible to describe a man's life and work in one word, that of Mr. Coit could be written in the single, comprehensive word, "gentleman".

While living in Champlain in his youth, Mr. Coit met Miss Caroline Morse whom he afterward married, and who, with two sons and two daughters, survives him.

Mr. Coit was a member of the Protestant Episcopal Church, and was connected with its affairs officially for a number of years. He had been for thirty years a Member of the Manhattan Club of New York City.

Mr. Coit was elected a Fellow of the American Society of Civil Engineers on September 20th, 1872.

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ON CONCRETE AND REINFORCED CONCRETE: Joseph R. Worcester, J. E. Greiner, W. K. Hatt, Olaf Hoff, Richard L. Humphrey, Robert W. Lesley, Emil Swensson, A. N. Talbot.

ON ENGINEERING EDUCATION: Desmond FitzGerald, Onward Bates, D. W. Mead.

ON STEEL COLUMNS AND STRUTS: George H. Pegram, James H. Edwards, Clarence W. Hudson, Charles F. Loweth, Rudolph P. Miller, Ralph Modjeski, Frank C. Osborn, Lewis D. Rights, George F. Swain, Emil Swensson, Joseph R. Worcester.

ON MATERIALS FOR ROAD CONSTRUCTION: W. W. Crosby, A. W. Dean, H. K. Bishop, A. H. Blanchard, George W. Tillson, Nelson P. Lewis, Charles J. Tilden.

ON VALUATION OF PUBLIC UTILITIES: Frederic P. Stearns, Charles S. Churchill, Leonard Metcalf, William G. Raymond, Henry E. Riggs, Jonathan P. Snow, William J. Wilgus.

TO INVESTIGATE CONDITIONS OF EMPLOYMENT OF, AND COMPENSATION OF, CIVIL ENGINEERS: Nelson P. Lewis, S. L. F. Deyo, Dugald C. Jackson, William V. Judson, George W. Tillson, C. F. Loweth, John A. Bensel.

TO CODIFY PRESENT PRACTICE ON THE BEARING VALUE OF SOILS FOR FOUNDATIONS, ETC.: Robert A. Cummings, Edwin Duryea, Jr., E. G. Haines, Allen Hazen, James C. Meem, Walter J. Douglas.

ON A NATIONAL WATER LAW: F. H. Newell, George G. Anderson, Charles W. Comstock, Clemens Herschel, W. C. Hoad, Robert E. Horton, John H. Lewis, Charles D. Marx, Gardner S. Williams.

ON FLOODS AND FLOOD PREVENTION: C. McD. Townsend, John A. Bensel, T. G. Dabney, C. E. Grunsky, Morris Knowles, J. B. Lippincott, Daniel W. Mead, John A. Ockerson, Arthur T. Safford, Charles Saville, F. L. Sellew.

TO REPORT ON STRESSES IN RAILROAD TRACK: A. N. Talbot, A. S. Baldwin, J. B. Berry, G. H. Bremner, John Brunner, W. J. Burton, Charles S. Churchill, W. C. Cushing, Robert W. Hunt, George W. Kittredge, Paul M. LaBach, C. G. E. Larsson, William McNab, G. J. Ray, Albert F. Reichmann, F. E. Turneaure, J. E. Willoughby.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

TELEPHONE NUMBER........................1446 Circle.
CABLE ADDRESS......................"Ceas, New York."

Vol. XLII. APRIL, 1916. No. 4.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PROCEEDINGS

SOCIETY AFFAIRS

CONTENTS

MINUTES OF MEETINGS

OF THE SOCIETY

March 15th, 1916.—The meeting was called to order at 8.30 P. M.; J. Waldo Smith, M. Am. Soc. C. E., in the chair; Chas. Warren Hunt, Secretary; and present, also, 141 members and 24 guests.

A paper by George Henry Ellis, Assoc. M. Am. Soc. C. E., entitled "The Flow of Water in Irrigation Channels", was presented by the Secretary, who also read a communication on the subject from H. B. Muckleston, M. Am. Soc. C. E.

Mr. H. E. Berger, Jr., a member of the American Red Cross expedition to Serbia, addressed the meeting and described the sanitary work accomplished, illustrating his remarks with lantern slides.

The Secretary announced the election of the following candidates on March 14th, 1916:

As Members

John Jarrett Albertson, Magnolia, N. J.
Isidore Cohen, Chicago, Ill.
Robert Lee Faris, Washington, D. C.
Herman Hall, New Orleans, La.
Audley Hart Stow, Pocahontas, Va.
Luis Velez, Caracas, Venezuela.

As Associate Members

Ames Scribner Albro, El Paso, Tex.
Hurieosco Austill, Mobile, Ala.
Edward Morris Bassett, Swarthmore, Pa.
William Purdy Benjamin, Albany, N. Y.
Louis Sterling Boggess, Tagbilaran, Philippine Islands
Clarence Nicholas Bott, New Orleans, La.
Henry Lee Bowlby, Portland, Ore.
Harvey Foreman Brown, Bryan, Ohio
Frank Rupert Burnette, Whitney, N. C.
John Cantley, Philadelphia, Pa.
William Nelson Carey, St. Paul, Minn.
Albert Friedrich Chittenden, Seattle, Wash.
John Abell Cleveland, Guayaquil, Ecuador
Frank Morgan Cortelyou, Vancouver, Wash.
James Cowin, Winnipeg, Man., Canada
Isidore Delson, New York City
Frank Doughty, San Francisco, Cal.
Harry Bayard Friedman, Detroit, Mich.
James Moseley Gilman, Seattle, Wash.
Moses Josiah Guyton, Dublin, Ga.
Henry Dennis Hammond, New York City
Walter Andrew Hitchcock, Washington, D. C.
Ivan Edgar Houk, Dayton, Ohio
Charles Melville Jenkins, Seattle, Wash.
Moritz Kahn, London, England
Ralph Long Kell, Altoona, Pa.
Egerton Wales Kibbey, International Falls, Minn.
John Edward Langley, Southport, N. C.
Thomas Keith Legaré, Columbia, S. C.
Charles Henry Levy, New York City
Chester Russel Logan, Springfield, Ill.
Thomas Alexander Lowe, Seneca Falls, N. Y.

Conde Balcom McCullough, Ames, Iowa
Charles Rex McNiece, East Cleveland, Ohio
Robert Joseph O'Meara, New York City
Bernard John O'Rourke, Utica, N. Y.
Lawrence Gilbert Parker, Chicago, Ill.
Marion Stuart Plumley, Edgewood Park, Pa.
Charles Henry Purcell, Portland, Ore.
Eugene Webster Robinson, San Antonio, Tex.
Alfred James Salisbury, Jr., Calipatria, Cal.
Allen Jeter Saville, Richmond, Va.
Wilhelm Rolf Oscar Holmboe Schenstrom, New York City
Rudolph Schweizer, Jr., Ridgefield Park, N. J.
Ray Seely, Hammond, Ind.
Oscar A. Seward, Jr., Beaumont, Tex.
Edward Gwyn Sheibley, El Paso, Tex.
Arvid Henry Sjovall, Capiz, Philippine Islands
Walter Talbot Spalding, Honolulu, Hawaii
Spencer Wilson Stewart, New York City
William Claude Swett, Pocatello, Idaho
Presley Morgan Taylor, Chevy Chase, Md.
Laurence Kimball Thompson, Phœnix, Idaho
Freeman Eugene Towle, Bath, N. Y.
Homer Root Turner, Windsor, Conn.
Isham Gano Webb, San Francisco, Cal.
Charles Henry Wondries, Colton, Cal.
Jesse Clarke Wright, Los Angeles, Cal.
Rudolph Charles Wueste, Bonita, Cal.

As Associates

Louis Mitchell, Syracuse, N. Y.
Arthur Graham Robbins, Boston, Mass.

As Juniors

Robert Sumter Anderson, Oakland, Cal.
Victor Hugo Bell, Calexico, Cal.
George Blanchard Blackstone, Hastings, Nebr.
Harry Young Carson, New York City
Harry de Laveaga Cebrian, Boston, Mass.
William Richard Cobb, Oakland, Cal.
Herbert Arthur Davies, Roanoke, Va.
Alexander Hall Ellison, Duluth, Minn.
Frederic Herbert Hapgood, Holyoke, Mass.
Plinio Ignelzi, Pittsburgh, Pa.
Henry Gardner Lehrbach, Conneaut, Ohio

John Francis Malone, Jr., Buffalo, N. Y.
Floyd August Nagler, Ann Arbor, Mich.
Franklyn William Oatman, Sacramento, Cal.
Frank John Oleri, New York City
Bartram Ashmead Owen, Philadelphia, Pa.
David Lindsay Struthers, Wilmington, N. C.
Harry Tidd, Kansas City, Mo.
Yung Tso Tong, Tientsin, China
Clarence Curtis Tracy, Palmerton, Pa.
Earle Chester Waite, Allentown, Pa.

The Secretary announced the transfer of the following candidates on March 14th, 1916:

From Associate Member to Member

Edward Franklin Atwood, Cambridge, Mass.
Philip Herrick Dater, Portland, Ore.
Theodore Lovel Donner Hadwen, Chicago, Ill.
Charles Chase Hurlbut, New York City
James Edgar Jenkins, New York City
Sigvald Johannesson, Upper Montclair, N. J.
Charles Johnson, New Orleans, La.
Joel DeWitt Justin, Chippewa Falls, Wis.
Charles Sumner Lambie, Denver, Colo.
William Caswell Smith Lemen, Savannah, Ga.
Carlos Lobo, Brooklyn, N. Y.
William Ainsworth McIntyre, Philadelphia, Pa.
Myron Hall Peck, Berkeley, Cal.
Charles Edwards Perry, Albany, N. Y.
Leland Sylvan Rosener, San Francisco, Cal.
Walter Rowland, Balboa Heights, Canal Zone, Panama
Harry Francis Sawtelle, Boston, Mass.
Zenas Harrison Sikes, Yonkers, N. Y.
William Wentworth Stevens, Shanghai, China

From Associate to Member

William Aiken Starrett, New York City

From Junior to Associate Member

Pendleton Beall, Cincinnati, Ohio
Isadore Ellis Behrman, Baltimore, Md.
Harold Burd Catlin, Brooklyn, N. Y.
Harold Farnsworth Gray, Palo Alto, Cal.
Shortridge Hardesty, Kansas City, Mo.
Hudson Bridge Hastings, Portland, Ore.

Clifford Murray Hathaway, Springfield, Ill.
Harry Riddel Hayes, Utica, N. Y.
Harry Albertus Helling, Liberty, N. Y.
Frank C. Huntsman, Alliance, Nebr.
George Henry Knutson, Jackson, Mich.
Carl Wayne Mengel, Wenona, N. C.
Edgar Alva Norwood, Medford Hillside, Mass.
Henry Brackette Parker, Delmar, N. Y.
Robert Lawrence Rolfe, Memphis, Tenn.
Lewis Ruffner Smith, Jr., Bakersfield, Cal.
Sidney Davis Strong, Sault Ste. Marie, Mich.
Edward Walter Wall, Montreal, Que., Canada

The Secretary announced the following deaths:

William Sooy Smith, of Medford, Ore., elected Member, January 17th, 1872; died March 4th, 1916.

Theodore Voorhees, of Philadelphia, Pa., elected Member, May 6th, 1885; died March 12th, 1916.

George Lenox Crawford, of Denver, Colo., elected Associate Member, September 3d, 1912; date of death unknown.

Adjourned.

April 5th, 1916.—The meeting was called to order at 8.30 P. M.; Director Arthur S. Tuttle in the chair; Chas. Warren Hunt, Secretary; and present, also, 124 members and 14 guests.

The minutes of the meetings of February 16th and March 1st, 1916, were approved as printed in *Proceedings* for March, 1916.

A paper by A. C. Janni, M. Am. Soc. C. E., entitled "Method of Designing a Rectangular Reinforced Concrete Flat Slab, Each Side of Which Rests on Either Rigid or Yielding Supports", was presented by the author. The Secretary presented by title a communication on the subject from Edward Godfrey, M. Am. Soc. C. E. The paper was discussed by Ernst F. Jonson, Assoc. M. Am. Soc. C. E., and the author.

The proposed movement of Society Headquarters was discussed. The Secretary read a letter which he had addressed to E. T. Thurston, Secretary of the San Francisco Association of Members, Am. Soc. C. E., in reply to certain questions relating to the proposed movement of Society Headquarters, and stated that, at the suggestion of the President, copies of this letter had been forwarded to each of the fifteen Local Associations. The Secretary also read correspondence with Edgar Marburg, Vice-President of the Philadelphia Association of Members, Am. Soc. C. E., and a communication from R. H. McPherson, M. Am. Soc. C. E., on the same subject.

The subject was discussed by President E. L. Corthell, Messrs. W. J. Gillen, Clemens Herschel, R. A. MacGregor, Ernst F. Jonson, G. T. Macnab, and W. H. Burr.

The Secretary announced the following deaths:

DANIEL BURKE DUNN, of Macon, Ga., elected Member, December 2d, 1891; died March 18th, 1916.

ASA BETTS FITCH, of Hollywood, Cal., elected Member, March 5th, 1884; died March 11th, 1916.

GEORGE AIKEN GILFILLAN, of Pittsburgh, Pa., elected Member, December 6th, 1905; died March 13th, 1916.

CARL ROBERT GRIMM, of Neuwied-am-Rhein, Germany, elected Member, June 4th, 1890; died February 15th, 1916.

WILLIAM EDWIN HOYT, of Rochester, N. Y., elected Member, March 5th, 1884; died April 2d, 1916.

ERASMUS DARWIN LEAVITT, of Cambridge, Mass., elected Member, July 2d, 1873; died March 11th, 1916.

CHARLES JEPTHA HILL WOODBURY, of Boston, Mass., elected Member, December 3d, 1884; died March 20th, 1916.

ARTHUR FRANCIS WROTNOWSKI, of Hermosillo, Son., Mexico, elected Member, July 12th, 1877; date of death unknown.

PHILIP HENRY PARTHESIUS, of Troy, N. Y., elected Associate Member, November 1st, 1910; died February 16th, 1915.

WILLIAM THOMAS SHAW, of Middleboro, Mass., elected Associate Member, June 30th, 1910; date of death unknown.

JAMES MADISON WARNER, of Syracuse, N. Y., elected Junior, April 6th, 1909; Associate Member, December 3d, 1913; died March 9th, 1916.

Adjourned.

ANNOUNCEMENTS

The House of the Society is open from 9 A. M. to 10 P. M., every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

FUTURE MEETINGS

May 3d, 1916—8.30 P. M.—This will be a regular business meeting. A paper by H. H. Wolff, M. Am. Soc. C. E., entitled "The Design of a Drift Barrier Across White River, near Auburn, Washington", will be presented for discussion.

This paper is printed in this number of *Proceedings*.

ANNUAL CONVENTION

The Forty-eighth Annual Convention of the Society will be held at Pittsburgh, Pa., from June 27th to 30th, 1916, inclusive.

Arrangements for the Convention are in the hands of the following Local Committee:

George S. Davison, *Chairman,*

J. A. Atwood,	D. W. McNaugher,
R. A. Cummings,	Emil Swensson,
Richard Khuen,	E. B. Taylor,
Morris Knowles,	W. G. Wilkins,

Paul L. Wolfel.

The Committee is actively engaged in preparing a programme, and it is expected that a preliminary circular will soon be issued to the membership.

SEARCHES IN THE LIBRARY

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

It sometimes happens that references are found which are not readily accessible to the person for whom the search is made. In that case the material may be reproduced by photography, and this can be done for members at the cost of the work to the Society, which is small. This method is particularly useful when there are drawings or figures in the text, which would be very expensive to reproduce by hand.

PAPERS AND DISCUSSIONS

Members and others who take part in the oral discussions of the papers presented are urged to revise their remarks promptly. Written communications from those who cannot attend the meetings should be sent in at the earliest possible date after the issue of a paper in *Proceedings.*

All papers accepted by the Publication Committee are classified by the Committee with respect to their availability for discussion at meetings.

Papers which, from their general nature, appear to be of a character suitable for oral discussion, will be published as heretofore in *Proceedings*, and set down for presentation to a future meeting of the Society, and on these, oral discussions, as well as written communications, will be solicited.

All papers which do not come under this heading, that is to say, those which, from their mathematical or technical nature, in the opinion of the Committee, are not adapted to oral discussion, will not be scheduled for presentation to any meeting. Such papers will be published in *Proceedings* in the same manner as those which are to be presented at meetings, but written discussions only will be requested for subsequent publication in *Proceedings* and with the paper in the volumes of *Transactions.*

The Board of Direction has adopted rules for the preparation and presentation of papers, which will be found on page 429 of the August, 1913, *Proceedings.*

LOCAL ASSOCIATIONS OF MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

San Francisco Association

The San Francisco Association of Members of the American Society of Civil Engineers holds regular bi-monthly meetings, with banquet, and weekly informal luncheons. The former are held at 6 P. M., at the Palace Hotel, on the third Tuesday of February, April, June, August, and October, and the third Friday of December, the last being the Annual Meeting of the Association.

Informal luncheons are held at 12.15 P. M., every Wednesday, and the place of meeting may be ascertained by communicating with the

Secretary of the Association, E. T. Thurston, 713 Mechanics' Institute, 57 Post Street.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in San Francisco, and any such member will be gladly welcomed as a guest.

Colorado Association

The meetings of the Colorado Association of Members of the American Society of Civil Engineers (Denver, Colo.) are held on the second Saturday of each month, except July and August. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary, L. R. Hinman, 1400 West Colfax Ave., Denver, Colo. The meetings are usually preceded by an informal dinner. Members of the American Society of Civil Engineers will be welcomed at these meetings.

Weekly luncheons are held on Wednesdays, at 12.30 P. M., at Clarke's Restaurant, 1632 Champa Street.

Visiting members are urged to attend the meetings and luncheons.

(Abstract of Minutes of Meeting)

February 12th, 1916.—The meeting was called to order at the Denver Athletic Club; Past-President H. S. Crocker, in the chair; L. R. Hinman, Secretary; and present, also, 9 members and 2 guests.

The minutes of the meeting of January 15th, 1916, were read and approved.

Messrs. J. E. Field, T. W. Jaycox, and T. L. Wilkinson were appointed a committee to report on the proposed change of headquarters of the American Society of Civil Engineers.

Messrs. L. B. Curtis, A. L. Fellows, and R. S. Sumner were appointed a committee to draft resolutions on the death of George L. Crawford, Assoc. M. Am. Soc. C. E.

Mr. H. S. Crocker reported that the Weather Bureau Committee of the Board of Direction had recommended that Congress be asked to appropriate additional funds for observations and obtaining other valuable information in the higher altitudes.

F. W. Whiteside, M. Am. Soc. C. E., addressed the meeting on "Coal Mining in Colorado", illustrating his remarks with lantern slides. The subject was generally discussed, and a vote of thanks was tendered to Mr. Whiteside for his interesting and instructive address.

Adjourned.

Atlanta Association

The Atlanta Association of Members of the American Society of Civil Engineers was organized on March 14th, 1912. The Association holds its meetings at the University Club, Atlanta, Ga.

At the meeting of the Association on January 9th, 1915, the following officers were elected for the ensuing year: President, Park A. Dallis; First Vice-President, B. M. Hall; Second Vice-President, P. H. Norcross; Secretary-Treasurer, T. B. Branch.

Baltimore Association

The Baltimore Association of Members of the American Society of Civil Engineers was organized on May 6th, 1914, and the proposed

Constitution was approved by the Board of Direction at its meeting of September 2d, 1914.

At the meeting of the Association on May 5th, 1915, the following officers were elected: President, Thomas D. Pitts; Secretary-Treasurer, Charles J. Tilden; Directors, J. E. Greiner, C. W. Hendrick, B. P. Harrison, B. T. Fendall, Mason D. Pratt, R. Keith Compton, R. B. Morse, and H. G. Shirley.

Cleveland Association

The proposed Constitution of the Cleveland Association of Members of the American Society of Civil Engineers was considered and approved by the Board of Direction of the Society on January 6th, 1915.

At the meeting of the Association on December 18th, 1915, the following officers were elected for the ensuing year: President, Robert Hoffmann; Vice-President, Wilbur J. Watson; and Secretary-Treasurer, George H. Tinker.

Louisiana Association

At the meeting of the Louisiana Association of Members of the American Society of Civil Engineers (New Orleans, La.), on April 14th, 1915, the following officers were elected for the ensuing year: J. F. Coleman, President; W. B. Gregory and A. M. Shaw, Vice-Presidents; Ole K. Olsen, Treasurer; and E. H. Coleman, Secretary.

Northwestern Association

The proposed Constitution of the Northwestern Association of Members of the American Society of Civil Engineers (St. Paul and Minneapolis, Minn.) was considered and approved by the Board of Direction of the Society on November 4th, 1914.

The officers of the Association are as follows: President, W. L. Darling; First Vice-President, George L. Wilson; Second Vice-President, L. W. Rundlett; Secretary, R. D. Thomas; and Treasurer, A. F. Meyer.

Philadelphia Association

The meetings of the Philadelphia Association of Members of the American Society of Civil Engineers are held at the Engineers' Club of Philadelphia, 1317 Spruce Street.

The officers of the Association are as follows: President, Edward B. Temple; Vice-Presidents, Edgar Marburg and John Sterling Deans; Directors, J. W. Ledoux, H. S. Smith, Henry H. Quimby, and George A. Zinn; Past-Presidents, George S. Webster and Richard L. Humphrey; Treasurer, S. M. Swaab; and Secretary, W. L. Stevenson.

Portland, Ore., Association

At the Annual Meeting of the Association on September 28th, 1915, the following officers were elected for the ensuing year: President, J. P. Newell; First Vice-President, John T. Whistler; Second Vice-President, E. B. Thomson; Treasurer, Russell Chase; and Secretary, J. A. Currey.

(Abstract of Minutes of Meeting)

March 6th, 1916.—The meeting was called to order in the Chamber of Commerce Building; President J. P. Newell in the chair; J. A.

Currey, Secretary. T. Warren Allen, Chief Engineer of the Forestry and Park Road Bureau, and B. J. Finch, Senior Engineer of the Highway Bureau, Department of the Interior, were present as guests of the Association.

Mr. J. W. Cunningham was appointed a member of the committee to investigate costs of hard surfacing roads in Multnomah County, to succeed Mr. M. E. Reed, who had resigned on account of absence from the city.

A request of the Library Association of Portland that the Portland Association ask the American Society of Civil Engineers to have its *Proceedings* indexed in the Industrial Art Index, was referred to the Board of Control.

Mr. George C. Mason was appointed a delegate to represent the Association at the Northwest Mining Convention to be held in Spokane March 20th to 24th, 1916.

The President was instructed to wire Oregon's Representatives in Congress, urging them to support the bills providing for military training in educational institutions.

The report of the Committee of the Board of Direction on the Licensing of Architects was read and freely discussed. The consensus of opinion was that no immediate action was necessary as the engineering and architectural associations in Portland are working in close harmony.

The matter of the proposed change of headquarters of the parent Society was discussed at considerable length by nearly all the members present, both sides of the question being argued. The object of the discussion was to bring out reasons for and against the proposed merger, but as action is to be by individual vote, the Association refrained from expressing any opinion. After the business meeting there was an informal discussion on road building in which Messrs. Allen and Finch expressed valuable ideas.

Mr. E. B. MacNaughton, Chairman of the Committee to investigate the cost of hard surface roads in Multnomah County reported briefly on the work, and the Committee was authorized to have a search made in the Library of the Society as to the costs of pavements of various types.

Adjourned.

St. Louis Association

The proposed Constitution of the St. Louis Association of Members of the American Society of Civil Engineers was considered and approved by the Board of Direction of the Society on October 7th, 1914.

The following officers have been elected: President, J. A. Ockerson; First Vice-President, Edward E. Wall; Second Vice-President, F. J. Jonah; Secretary-Treasurer, Gurdon G. Black. The meetings of the Association are held at the Engineers' Club Auditorium.

San Diego Association

The San Diego Association of Members of the American Society of Civil Engineers was organized on February 5th, 1915, and officers have been elected, as follows: President, George Butler; Vice-President, Willis J. Dean; and Secretary-Treasurer, J. R. Comly.

At its meeting of September 20th, 1915, the Board of Direction considered and approved the proposed Constitution of the San Diego Association of Members of the American Society of Civil Engineers.

Seattle Association

The Seattle Association of Members of the American Society of Civil Engineers was organized on June 30th, 1913.

The officers of the Association for 1916 are as follows: President, A. O. Powell; Vice-President, Joseph Jacobs; and Secretary-Treasurer, Carl H. Reeves.

(Abstract of Minutes of Meetings)

February 28th, 1916.—The meeting was called to order at The Northold Inn; President A. O. Powell in the chair; Carl H. Reeves, Secretary; and present, also, 21 members and guests.

The minutes of the Annual Meeting, held on January 31st, 1916, were read and approved.

The resignation of Mr. H. M. Bringhurst as a member of the Association, owing to removal from the city, was read and accepted.

On motion, duly seconded, the request of the Pacific Northwest Society of Engineers, received through its Secretary, Mr. Harrison S. Taft, to publish the paper entitled "The New Water Supply of Victoria", which was presented by C. H. Rust, M. Am. Soc. C. E., at the Annual Meeting of the Association, was granted.

A letter from Charles Warren Hunt, Secretary of the Society, containing the Report of the Committee of the Board of Direction on the Licensing of Architects, etc., was read and referred to the Legislative Committee.

On motion, duly seconded, the Soils Committee and the Legislative Committee were continued.

The proposed affiliation of the Society with the United Engineering Society as an additional Founder Society, was the principal topic of discussion at the meeting. Letters from Charles Warren Hunt, Secretary of the Society, and J. A. Ockerson, Past-President, Am. Soc. C. E., stating their views on the matter, were read.

On motion, duly seconded, the Secretary was instructed to correspond with men in close touch with the matter of the proposed merger and question them regarding the disputed points.

On motion, duly seconded, it was decided to publish and distribute a Year Book of the Association for 1916.

Adjourned.

March 27th, 1916.—The meeting was called to order at The Northold Inn; President A. O. Powell in the chair; Carl H. Reeves, Secretary; and present, also, 26 members and guests.

The minutes of the meeting of February 28th, 1916, were read and approved.

The President called attention to the death of Mr. W. Frank Carr, a member of the Association, on February 2d, 1916, and stated that the Association had been represented at the funeral, that an appropriate floral tribute had been sent, and that he, as President, had expressed by letter to the family the sympathy of the Association.

The President announced the following appointments on the Standing Committees of the Association: Legislative Committee, H. L. Gray, Chairman, A. H. Fuller, T. A. Noble, F. H. Fowler, Paul P. Whitham, T. G. McCrory, and J. B. Warrack; Soils Committee: A. W. Munster, Chairman, Charles Albertson, A. W. Sargent, J. R. West, and G. R. Hawes.

The President called attention to the Progress Report of the Special Committee of the Society on a National Water Law, published in the December, 1915, *Proceedings*, and stated that the Committee did not include a member from Washington, and only one from Oregon, the two largest water-power States in the Union. On motion, duly seconded, the President was instructed to take up, with the Board of Direction, the matter of the representation of the State of Washington on that Special Committee.

The question of "A National Water Law", with particular reference to the latest Progress Report of the Special Committee on that subject, was referred to the Legislative Committee.

The attention of the Association was called to the National Reclamation Conference, held in Washington, D. C., on March 25th, 1916, and also to letters from the Philadelphia and Cleveland Associations relating to the revision of the Constitution of the Society.

In continuation of the discussion of the proposed affiliation of the Society with the United Engineering Society as an additional Founder Society, the Secretary read letters from Messrs. J. A. Ockerson, Virgil G. Bogue, and Clemens Herschel. Reference was also made to the editorial in *Engineering Record* of March 18th, 1916, relating to this subject.

On motion, duly seconded, it was decided that it is the sense of the Association that the affiliation of the Society with the United Engineering Society as an additional Founder Society should be effected.

On motion, duly seconded, it was decided that it is the sense of the Association that its members should vote for Proposition "A", and the Secretary was instructed to notify the membership of this action.

Adjourned.

Southern California Association

The Southern California Association of Members of the American Society of Civil Engineers (Los Angeles, Cal.) holds regular bimonthly meetings, with banquet, on the second Wednesday of February, April, June, August, October, and December, the last being the Annual Meeting of the Association.

Informal luncheons are held at 12.15 P. M. every Wednesday, and the place of meeting may be ascertained from the Secretary of the Association, W. K. Barnard, 701 Central Building, Los Angeles, Cal.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in Los Angeles, and any such member will be gladly welcomed as a guest at any of the meetings or luncheons.

The officers of the Association for 1916, are as follows: President, William Mulholland; First Vice-President, H. Hawgood; Second Vice-President, L. C. Hill; Secretary, W. K. Barnard; and Treasurer, C. H. Lee.

Spokane Association

The proposed Constitution of the Spokane Association of Members of the American Society of Civil Engineers was considered and approved by the Board of Direction of the Society on March 4th, 1914. Ulysses B. Hough is President.

Texas Association

The proposed Constitution of the Texas Association of Members of the American Society of Civil Engineers was considered and approved by the Board of Direction of the Society on December 31st, 1913. The headquarters of the Association is Dallas, Tex. John B. Hawley is President.

MINUTES OF MEETINGS OF SPECIAL COMMITTEES TO REPORT UPON ENGINEERING SUBJECTS

Special Committee on Concrete and Reinforced Concrete

January 18th, 1916.—The meeting was called to order at 2.30 P. M., in the rooms of the American Society of Mechanical Engineers, 29 West 39th Street, New York City. Present, J. R. Worcester (Chairman), William K. Hatt, Olaf Hoff, Robert W. Lesley, Arthur N. Talbot, and Richard L. Humphrey (Secretary).

The Chairman called attention to the budget covering the expenses of the Committee to July 1st, 1916. The Committee agreed that the Society should be requested to provide $1 000 toward the expenses of the Committee (in addition to $1 000 required for the mileage allowed its members).

The report of the Sub-Committee on Aggregates was considered, and adopted tentatively, with the understanding that it would come up for final action at the March meeting of the Committee. The report of the Sub-Committee on Design, particularly its proposed requirements for flat slab design, was discussed, and it was decided to hold a meeting in Chicago at which those interested in flat slab design should be invited to attend and present their views.

The report of the Sub-Committee on Reinforcement was considered.

February 15th and 17th, 1916.—The meeting was held at the Auditorium Hotel, Chicago, Ill. Present, William K. Hatt, Robert W. Lesley, Arthur N. Talbot, and Richard L. Humphrey (Secretary). There were present, by invitation, the following members of the Joint Committee: Richard L. Humphrey, A. L. Johnson, Robert W. Lesley, Sanford E. Thompson (represented by Edward Smulski), and F. E. Turneaure.

There were also present, by invitation: W. P. Anderson, L. R. Cobb, T. L. Condron, Arthur R. Lord, A. F. Lindau, A. J. Maynard, H. B. MacMillan, John W. Mushan, A. W. Slater, H. C. Turner, and O. Westergaard. Communications from Edward Godfrey, J. W. Moffett, and Sanford E. Thompson were read.

The tentative requirements for flat slab design, proposed by the Sub-Committee on Design, were discussed.

A recess was taken from 10 A. M. to 2.30 P. M., and the meeting adjourned at 6 P. M.

The Committee met at the Auditorium Hotel on Thursday, February 17th, 1916, at 9.30 A. M., devoted the entire session to the discussion of flat slab design, and adjourned at 12 o'clock, noon.

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms, and at all meetings:

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American Institute of Mining Engineers, 29 West Thirty-ninth Street, New York City.

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Engineers' Club of Baltimore, 6 West Eager Street, Baltimore, Md.

Engineers' Club of Kansas City, E. B. Murray, Secretary, 920 Walnut Street, Kansas City, Mo.

Engineers' Club of Minneapolis, 17 South Sixth Street, Minneapolis, Minn.

Engineers' Club of Philadelphia, 1317 Spruce Street, Philadelphia, Pa.

Engineers' Club of St. Louis, 3817 Olive Street, St. Louis, Mo.

Engineers' Club of Toronto, 96 King Street, West, Toronto, Ont., Canada.

Engineers' Club of Trenton, Trent Theatre Building, 12 North Warren Street, Trenton, N. J.

Engineers' Society of Northeastern Pennsylvania, 415 Washington Avenue, Scranton, Pa.

Engineers' Society of Pennsylvania, 31 South Front Street, Harrisburg, Pa.

Engineers' Society of Western Pennsylvania, 2511 Oliver Building, Pittsburgh, Pa.

Institute of Marine Engineers, The Minories, Tower Hill, London, E., England.

Institution of Engineers of the River Plate, Calle 25 de Mayo 195, Buenos Aires, Argentine Republic.

Institution of Naval Architects, 5 Adelphi Terrace, London, W. C., England.

Junior Institution of Engineers, 39 Victoria Street, Westminster, S. W., London, England.

Koninklijk Instituut van Ingenieurs, The Hague, The Netherlands.

Louisiana Engineering Society, State Museum Building, Chartres and St. Ann Streets, New Orleans, La.

Memphis Engineers' Club, Memphis, Tenn.

Midland Institute of Mining, Civil and Mechanical Engineers, Sheffield, England.

Montana Society of Engineers, Butte, Mont.

North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne, England.

Oesterreichischer Ingenieur- und Architekten-Verein, Eschenbachgasse 9, Vienna, Austria.

Oregon Society of Civil Engineers, Portland, Ore.

Pacific Northwest Society of Engineers, 312 Central Building, Seattle, Wash.

Rochester Engineering Society, Rochester, N. Y.

Sachsischer Ingenieur- und Architekten-Verein, Dresden, Germany.

Sociedad Colombiana de Ingenieros, Bogota, Colombia.

Sociedad de Ingenieros del Peru, Lima, Peru.

Societe des Ingenieurs Civils de France, 19 rue Blanche, Paris, France.

Society of Engineers, 17 Victoria Street, Westminster, S. W., London, England.

Svenska Teknologforeningen, Brunkebergstorg 18, Stockholm, Sweden.

Tekniske Forening, Vestre Boulevard 18–1, Copenhagen, Denmark.

Western Society of Engineers, 1737 Monadnock Block, Chicago, Ill.

ACCESSIONS TO THE LIBRARY

(From March 2d to April 3d, 1916)

DONATIONS*

RAILWAY REGULATION:

An Analysis of the Underlying Problems in Railway Economics from the Standpoint of Government Regulation. By I. Leo Sharfman. Morocco, 8½ x 6 in., 6 + 230 pp. Chicago, La Salle Extension University, 1915. $2.00.

As stated in the secondary title, the author's aim has been to present an analysis of the leading problems in railway economics from the standpoint of Government regulation, the vital and inseparable relationship in railway transportation between legal rules and business welfare, between railway economics and railway regulation, having served, it is said, as the source and foundation of the entire analysis and discussion. The author, it is stated, has traced the historical development of railway transportation only in as far as early conditions and past events have thrown light on the meaning and significance of current practices and present-day problems, but careful and detailed consideration has been given to the various stages in the growth of the American system of public control, both State and National, because the principles and methods of railway regulation, as applied in the United States to-day, are the results of gradual development. The text is illustrated with many concrete examples of railway regulation, and, at the end of each chapter, there is a list of test questions relative to the subject discussed in that chapter. There is also a list of selected books on the principles of railway economics and the law and development of railway regulation. The Contents are: The Extent and Importance of Railway Transportation; The Problem of Regulation; American Railway Development; Railway Competition; The Theory and Practice of Rate-Making; The Regulation of Railway Rates; Railway Discrimination; Regulation by the States; The Conflict Between State and Federal Authority; Federal Regulation; Note on Source Material; Selected Books; Index.

STUDIES IN THE COST OF URBAN TRANSPORTATION SERVICE.

By F. W. Doolittle, Assoc. M. Am. Soc. C. E., Director, Bureau of Fare Research, American Electric Railway Association. Cloth, 9½ x 6¼ in., illus., 23 + 467 pp. New York, American Electric Railway Association, 1916.

The results of the investigations made by the Bureau of Fare Research and embodied in this book, are offered, it is stated, to all who are interested in the common factors affecting street railway rates of fare and service, in the hope that they will assist in clearing up much of the misunderstanding that prevails as to the actual financial results of electric railway operation. The subject-matter, it is stated, is a comprehensive summary of costs and service factors, in which the costs incurred in creating, developing, and operating the street railway are discussed. This is followed by a study of the nature, tendency, and measurement of costs in street railway work, together with studies of the character and measurement of the services rendered. Finally, the general facts and principles, as outlined, are applied, it is said, to concrete and specific problems of costs involved in the extension of area served, of transfer privileges, in compliance with service demands, and in studies of rapid transit. There is also included a selected list of references on Valuation and Depreciation. The Contents are: Part I, The Occasion for Cost of Service; Part II, Elements of Cost; Part III, Elements of Service; Part IV, Special Problems; Part V, Regulation and the Cost of Service; Index.

SEWERAGE:

The Designing, Construction, and Maintenance of Sewerage Systems. By A. Prescott Folwell. Seventh Edition, Revised and Enlarged. Cloth, 9 x 6 in., illus., 10 + 540 pp. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Limited, 1916. $3.00.

The first edition of this book was issued in 1898, and, in the preface to that edition, it is stated that the author has undertaken to embody in one volume the most recent data and ideas relating to the subject and to treat in a comprehensive manner both the combined and separate systems. In this the seventh edition,

* Unless otherwise specified, books in this list have been donated by the publishers.

owing to the advance in knowledge and practice in methods of sewage disposal, Part IV, which relates to that subject, has been thoroughly revised, it is said, considerable changes having been made in those portions dealing with tank treatment, including the addition of all available information relative to the new process using activated sludge. The subject of the clarification of sewage has been discussed, it is said, at greater length, and the standard specifications recommended by the American Society of Municipal Improvements have been substituted for those prepared by the author and included in previous editions. There is also a new table containing a list of more than 900 sewage treatment plants in the United States, and the Appendix is devoted to a discussion of methods of testing sewage and sewage effluents. Although intended for the practicing engineer, the work, it is stated, has also been arranged for use as a textbook for engineering students, Parts I and II having been used as such by the author in his work. The Contents are: Part I, Designing: The System; Amount of Sewage; Flow in Sewers; Flushing and Ventilation; Collecting the Data; The Design; Detail Plans; Specifications, Contract, Estimate of Cost. Part II, Construction: Preparing for Construction; Laying Out the Work; Oversight and Measurement of Work; Practical Sewer Construction. Part III, Maintenance: House Connections and Drainage; Sewer Maintenance. Part IV, Sewage Disposal: Disposal by Dilution; Methods of Treatment; Appendix: Testing Sewage and Effluents; Index.

ELEVATORS:

A Practical Treatise on the Development and Design of Hand, Belt, Steam, Hydraulic, and Electric Elevators. By John H. Jallings. Cloth, $8\frac{1}{2}$ x $5\frac{3}{4}$ in., illus., 4 + 217 + 7 pp. Chicago, American Technical Society, 1915. $1.50.

The development of the elevator, from the crude hand elevator to its present state of efficiency, has been gradual, it is stated, and its history is practically that of the mechanical development of the times. In this book, the author, who has had fifty years' practical experience in elevator construction, has discussed this historical development through the hand, belt, steam, hydraulic, and electric types, and has described in detail their design and construction, particularly the modern types of hydraulic and electric elevators, together with their control methods, safety devices, motors, car suspensions, etc. The available literature on elevator design and construction is very meager, it is stated, and it is hoped that this volume will find a popular place in its field and supply a real demand. The Contents are: Part I, Hand-Power Elevators; Belt-Power Elevators; Worm and Gear. Part II, Steam Elevators; Hydraulic Elevators. Part III, Electric Elevators; Index.

BROWN'S DIRECTORY OF AMERICAN GAS COMPANIES:

Gas Statistics, 1915. Compiled and Corrected Annually by E. C. Brown. Cloth, $10\frac{3}{4}$ x 7 in., 51 + 872 pp. New York, "The Gas Age," 1915. $5.00. (Donated by the Compiler.)

The statistics relating to the 2 323 gas companies of the United States, Canada, Mexico, South America, etc., reported in this book are arranged alphabetically by States and cities, and are classified under the following heads: Manufactured (or artificial) gas companies, including coke-oven plants; natural gas companies; acetylene town plants; parent or operating companies, and public service commissions. Under each company are given the railroad and steamboat lines on which the city is located as well as the names of express companies serving that point, officers of the company, process, production, candle-power, miles of mains, gas-holder capacity, population of city, number of consumers, etc. In the Appendix are given financial data of the companies reported, officers, directors, and committees of American gas associations, as well as an alphabetical list of members of these associations. There is also a short list of books for gas engineers and three indexes, an Index to Contents, a Company Index, and a City and Town Index.

MILITARY PREPAREDNESS AND THE ENGINEER.

By Ernest F. Robinson, Assoc. M. Am. Soc. C. E. Cloth, $6\frac{3}{4}$ x $4\frac{1}{2}$ in., illus., 16 + 224 pp. New York, Clark Book Co., Inc., 1916. $1.50.

In order to outline, in a practical manner, the duties, responsibilities, and functions of the civilian engineer during the time immediately following his call to the colors, the author, it is stated, has addressed large meetings of engineers on the subject. These lectures, carefully revised and materially enlarged, are embodied in this volume with the hope that the contents will convey an idea of the opportunities and limitations that will confront the civilian engineer in the event of war, to show him what he can do to assist in preparedness against invasion, and how he must go about the matter. A large part of the technical matter contained in the work is based, it is said, on service manuals of the United States Army, and that in Chapter VII, on "Rifle Instruction," illustrates, it is stated, the methods devised and used by the author in his company of the New York National Guard. At the end of the book, the author has included a list of reading on military subjects for the civilian engineer, recommended by the Chief of Engineers, U. S. Army, and a list of engineer property carried by each engineer company in the field. The Chapter headings are: Introductory; How to Obtain a Military Training; The National Guard; Military Organization; Military Administration; Engineer Troops in the Field; Fire Action; Field Fortifications; Obstacles; Siege Works; Demolitions; Military Bridges; Topographical Sketching; Needs of the Engineers in War; Conclusion; Appendix I, List of Reading on Military Subjects for Civilian Engineers; Appendix II, List of Engineer Property Carried by a Company of Engineers in the Field.

GEODETIC SURVEYING.

By Edward R. Cary, M. Am. Soc. C. E. Cloth, $8\frac{1}{4}$ x $5\frac{1}{2}$ in., illus., 9 + 279 pp. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Limited, 1916. $2.50.

The author states that marked changes have occurred in the practice of geodetic surveying in the last 15 years. These changes have necessitated new methods of procedure, new equipment, new instruments, etc., etc., all of which are described and discussed herein in detail for the use of the engineering student. The methods described by the author are stated to be mainly those used by the United States Coast and Geodetic Survey in its work. The author has also included problems in Geodesy and their solutions, as well as many tables for use in geodetic work. It is stated that Geodetic Astronomy and the Method of Least Squares are taught separately from Geodetic Surveying in many schools and, for this reason, these subjects are discussed in this book in Appendices I and II. There is also a short list of books on Geodetic Surveying, Geodetic Astronomy, and the Method of Least Squares. The Contents are: Introduction; Reconnaissance; Base Lines; Horizontal Angles; Adjustment of Horizontal Angles; Computation of Geodetic Latitudes, Longitudes, and Azimuths; Map Projections; Trigonometric Leveling; Precise Leveling; Appendix I, Time, Longitude, Latitude and Azimuth; Appendix II, The Method of Least Squares; References: Books, etc., on Geodetic Surveying and Least Squares; Index.

THE MINING WORLD INDEX OF CURRENT LITERATURE

Vol. VIII, July-December, 1915. By George E. Sisley. Cloth, $9\frac{1}{2}$ x $6\frac{1}{4}$ in., 25 + 228 pp. Chicago, Mining World Company, 1915.

In a secondary title it is stated that this Index is an international bibliography of Mining and the Mining Sciences compiled and revised semi-annually from the Index of the World's Current Literature which appears weekly in *Mining and Engineering World*. The matter indexed is taken from periodicals published in America, Europe, Africa, and Australia, as well as papers read before engineering and technical societies, reports of Federal and State Geological Surveys and Mining Bureaus, and various new books on the subjects. These articles are arranged alphabetically by author under the subject, and the entries include author, title, brief digest of article, journal in which it appears, with date and page, number of pages, and the price. A system of cross-indexing is used in order to find readily all that is indexed of a particular mining or affiliated subject. Few changes have been made in this volume, it is stated, and these are of a minor nature. All articles on flotation, owing to its increasing importance, have been placed under a separate head and several other departments have undergone a closer classification, all changes having been made, it is said, with the object of producing a handy reference book. There are also a list of publications indexed, an authors' index, and a subject index. The Contents are: Part I, Geology and Mineralogy; Part II, Ores and Mineral Products; Part III, Technology; Part IV, Miscellaneous.

THE AUTHENTIC HISTORY OF THE UNITED STATES STEEL CORPORATION.

By Arundel Cotter. Cloth, 9 x 6 in., illus., 10 + 231 pp. New York, The Moody Magazine and Book Company, 1916.

The preface states that, in writing this History of the United States Steel Corporation, it is not the author's intention to compile a work of reference for the steel man, his idea being merely to describe the men who made it possible and to narrate, in as interesting a manner as possible, the principal events leading up to its incorporation, its objects, its policies, and their results on labor, the Corporation itself, and on industry generally. A very large number of the facts contained herein were obtained, it is stated, from the sworn testimony in the Government suit for the dissolution of the Corporation, and although many facts and events worthy of record have been omitted, the most salient features of the Corporation's history are said to have been included. The Contents are: Events Preceding the Organization; The Birth of the Big Company; Early History, 1901 to 1907; The Tennessee Purchase; The Men of the Corporation; Development of Export Trade; The Spirit of the Corporation; The Corporation's Implements; The Steel Towns; Safety First, Sanitation, Welfare; Questions of Policy; Investigations and the Dissolution Suit; Later History, 1907 to 1915; Statistics, Financial and Otherwise.

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Wyoming—State Geologist. 1 pam.
Yale Univ. 1 vol.

BY PURCHASE

Die Portland-Zement Fabrikation: Ein Handbuch für Ingenieure und Zementfabrikanten. Von Carl Naske. Dritte vollständig umgearbeitete und vermehrte Auflage. Leipzig.

Electric Railway Engineering. C. Francis Harding, Assisted by Dressel D. Ewing. Second Edition, Revised and Enlarged. New York and London, 1916.

The Gasoline Automobile. Prepared in the Extension Division of the University of Wisconsin by George W. Hobbs and Ben. G. Elliott. New York and London, 1915.

Refuse Disposal: A Practical Manual for Municipal Engineers, Members of Local Authorities, etc. By Ernest Matthews. Philadelphia and London, 1915.

Aufgaben aus der Technischen Mechanik. Von Ferdinand Wittenbauer. Dritte, vermehrte und verbesserte Auflage. 3 Band. Berlin, 1914.

Bahnenformeln: Gebrauchsfertige Formeln für einhüftige, zweistielige, dreieckförmige und geschlossene Rahmen aus Eisen oder Eisenbetonkonstruktion nebst Anhang mit sonderfällen Teilweise und ganz eingespannter Träger. Von A. Kleinlogel. Berlin, 1914.

Die Chemie der Hydraulischen Bindemittel: Wesen und Herstellung der Hydraulischen Bindemittel. Von Hans Kühl und Walter Knothe. Leipzig, 1915.

Poor's Manual of the Railroads of the United States, 1916. New York.

The Elements of Military Hygiene Especially Arranged for Officers and Men of the Line. By P. M. Ashburn. Boston and New York, 1915.

The Principles of Land Defence and Their Application to the Conditions of To-Day. By H. F. Thuillier. New York and London, 1902.

Grundzüge der Mengenlehre. Von Felix Hausdorff. Leipzig, 1914.

Reinigung und Beseitigung Städtischer und Gewerblicher Abwasser. Von A. Reich. Leipzig.

Forschungsarbeiten auf dem Gebiete des Ingenieurwesens. Herausgegeben vom Verein Deutscher Ingenieure. Hefte 180, 181, 182. Berlin, 1915.

The American Year Book: A Record of Events and Progress 1915. Edited by Francis G. Wickware, with Coöperation of a Supervisory Board Representing National Learned Societies. New York and London, 1916.

Principles and Practice of Electrical Engineering. By Alexander Gray. New York and London, 1914.

The Service of Coast Artillery. By Frank T. Hines and Franklin W. Ward. New York, 1910.

The Callendar Steam Tables. By H. L. Callendar. New York and London, 1915.

National Association of Railway Commissioners: Proceedings of the Twenty-Seventh Annual Convention held at San Francisco, Cal., October 12th-15th, 1915. New York.

A New Dictionary of the Portuguese and English Languages Enriched by a Great Number of Technical Terms Used in Commerce and Industry, in the Arts and Sciences, and Including a Great Variety of Expressions from the Language of Daily Life. By H. Michaelis. Fifth Edition. 2 Vol. Leipzig and London, 1914.

Die Eisenbahn Technik der Gegenwart: Ersten Band, Das Eisenbahn-Maschinenwesen. Herausgegeben von Bankhausen, Blum, Courtin und Weiss. Dritte umgearbeitete Auflage. 3 Vol. Wiesbaden, 1912.

Officers' Manual. By James A. Moss. Fifth Edition, Revised and Enlarged. Fort Leavenworth, Kans., and Menasha, Wis., 1911.

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SUMMARY OF ACCESSIONS

(From March 2d to April 3d, 1916)

Donations (including 10 duplicates)	324
By purchase	41
Total	365

MEMBERSHIP

(From March 3d to April 6th, 1916)

ADDITIONS

MEMBERS

Name and Address	Grade	Date of Membership.
ALBERTSON, JOHN JARRETT. Engr., Boroughs of Collingwood, Audubon, and Haddon Heights; County Engr., Camden County, Magnolia, N. J.		Mar. 14, 1916
COHEN, ISIDORE. Engr. in Chg. of Constr. Work, Witherspoon-Englar Co., 1250 Monadnock Blk., Chicago, Ill.		Mar. 14, 1916
COLLINS, CLARKE PELEG. San. Engr., City of Johnstown; Cons. Engr. (C. P. Collins & Co.), Otto Bldg., Johnstown, Pa.	Assoc. M. M.	June 4, 1902 Jan. 18, 1916
HADWEN, THEODORE LOVEL DONNER. Engr. of Masonry Constr., C., M. & St. P. Ry., 1347 Railway Exchange, Chicago, Ill.	Assoc. M. M.	Oct. 7, 1908 Mar. 14, 1916
HALL, HERMAN. Gen. Supt., La. South. R. R., 1241 North Hogan Ave., New Orleans, La.		Mar. 14, 1916
JENKINS, JAMES EDGAR. Supt., Cook Constr. Co., Ltd., 406 McGill Bldg., Montreal, Que., Canada (Res., 644 Riverside Drive, New York City)	Assoc. M. M.	Dec. 5, 1906 Mar. 14, 1916
JOHANNESSON, SIGVALD. Prin. Asst. Engr., I. R. T. Co., 361 North Fullerton Ave., Montclair, N. J.	Assoc. M. M.	Nov. 1, 1905 Mar. 14, 1916
JUSTIN, JOEL DEWITT. Res. Engr., Fargo Eng. Co., 43 East Elm St., Chippewa Falls, Wis.	Assoc. M. M.	Oct. 3, 1911 Mar. 14, 1916
LAMBIE, CHARLES SUMNER. Pres., The C. S. Lambie Co., 314 Tramway Bldg., Denver, Colo.	Jun. Assoc. M. M.	Oct. 1, 1901 Feb. 6, 1907 Mar. 14, 1916
LEMEN, WILLIAM CASWELL SMITH. Prin. Asst. Engr., U. S. Engr. Office, Savannah, Ga.	Assoc. M. M.	July 10, 1907 Mar. 14, 1916
LOBO, CARLOS. Borough Engr., 215 Midwood St., Brooklyn, N. Y.	Assoc. M. M.	May 3, 1905 Mar. 14, 1916
MCINTYRE, WILLIAM AINSWORTH. Chf. Rd. Engr., Assoc. of Am. Portland Cement Mfrs., 1202 North State St., Chicago, Ill.	Assoc. M. M.	Feb. 6, 1912 Mar. 14, 1916
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SAWTELLE, HARRY FRANCIS. Prin. Asst. Engr., Fay, Spofford & Thorndike, 308 Boylston St., Boston, Mass.	Assoc. M. M.	Mar. 6, 1907 Mar. 14, 1916

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SIKES, ZENAS HARRISON. Asst. Engr. of Structures, N. Y. C. R. R. Lines, East of Buffalo, Exterior Zone, Grand Central Terminal, New York City (Res., 333 Riverdale Ave., Yonkers, N. Y.)	Assoc. M. M.	June 30, 1910 Mar. 14, 1916
STARRETT, WILLIAM AIKEN. Archt. (Starrett & Van Vleck), 8 West 40th St., New York City (Res., Madison, N. J.)	Assoc. M. M.	Oct. 7, 1914 Mar. 14, 1916
STOW, AUDLEY HART. Chf. Engr., Pocahontas Consolidated Collieries Co., Inc., Pocahontas, Va		Mar. 14, 1916

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BASSETT, EDWARD MORRIS. Engr. and Estimator, Doyle & Co., 315 North Chester Rd., Swarthmore, Pa.......		Mar. 14, 1916
BEALL, PENDLETON. Engr. for D. P. Foley, 1344 Locust St., Cincinnati, Ohio......	Jun. Assoc. M.	June 6, 1911 Mar. 14, 1916
BEHRMAN, ISADORE ELLIS. Cons. Engr. (Houston & Behrman), 1121 East Baltimore St., Baltimore, Md..................	Jun. Assoc. M.	Oct. 4, 1910 Mar. 14, 1916
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BROWN, HARVEY FOREMAN. Civ. and Min. Engr., 200 South William St., Bryan, Ohio.................		Mar. 14, 1916
BURNETTE, FRANK RUPERT. Chf. Civ. Engr., Southern Aluminum Co., 304 Broadway, Piqua, Ohio.........		Mar. 14, 1916
CANTLEY, JOHN. Asst. Structural Engr., Bureau of Bldg. Inspection of Philadelphia, 317 City Hall, Philadelphia, Pa.................................		Mar. 14, 1916
CAREY, WILLIAM NELSON. With U. S. Engr. Corps, Box 654, St. Paul, Minn...........................		Mar. 14, 1916
CATLIN, HAROLD BURD. Room 911, Bureau of Sewers, Brooklyn, N. Y. (Res., 87 St. Nicholas Pl., New York City).........	Jun. Assoc. M.	April 2, 1912 Mar. 14, 1916
CORTELYOU, FRANK MORGAN. 1st and Washington Sts., Vancouver, Wash...........................		Mar. 14, 1916
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DOUGHTY, FRANK. Engr., Reclamation Dists. Nos. 536 and 773, 1104 Merchants Exchange, San Francisco, Cal..		Mar. 14, 1916
EVERETT, FREDERIC ELWIN. Highway Commr., State of New Hampshire, 56 Beacon St., Concord, N. H......		Dec. 6, 1915
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GRUNSKY, EUGENE LUCIUS. Res. Engr., Am. Eng. Corporation, 57 Post St., San Francisco, Cal..........		Nov. 3, 1915
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HAYES, HARRY RIDDEL. Commr. of Public Works, City Hall, Utica, N. Y.	Jun. Assoc. M.	Feb. 28, 1911 Mar. 14, 1916
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HITCHCOCK, WALTER ANDREW. Cons. Engr., 4921 Kenmore Ave., No. 2, Chicago, Ill.		Mar. 14, 1916
HOUK, IVAN EDGAR. Asst. Engr., Miami Conservancy Dist., Dayton, Ohio		Mar. 14, 1916
HUNTSMAN, FRANK C. Div. Engr., C., B. & Q. R. R., Box 1397, Alliance, Nebr.	Jun. Assoc. M.	Sept. 5, 1905 Mar. 14, 1916
KELL, RALPH LONG. Asst. Superv., P. R. R., 1609 Seventeenth Ave., Altoona, Pa.		Mar. 14, 1916
KIBBEY, EGERTON WALES. County Surv., Koochiching County, and City Engr., International Falls, Minn.		Mar. 14, 1916
KNUTSON, GEORGE HENRY. Civ. and Hydr. Engr., Fargo Eng. Co., Commonwealth Bldg., Jackson, Mich.	Jun. Assoc. M.	Aug. 31, 1909 Mar. 14, 1916
LEVY, CHARLES HENRY. Engr. in Executive Chg., Bureau of Design and Survey, 2100 Municipal Bldg., New York City		Mar. 14, 1916
LOGAN, CHESTER RUSSEL. 202 South Glenwood Ave., Springfield, Ill.		Mar. 14, 1916
LOWE, THOMAS ALEXANDER. Supt., Contr. C, Cayuga and Seneca Canal, 29 Walnut St., Seneca Falls, N. Y.		Mar. 14, 1916
McCULLOUGH, CONDE BALCOM. Designing Engr., Iowa State Highway Comm., Ames, Iowa		Mar. 14, 1916
McMULLEN, STANLEY HASTINGS. Orlando, Fla.		Nov. 3, 1915
McNIECE, CHARLES REX. Engr., The William Dall Co., 93 Carlyon Rd., East Cleveland, Ohio		Mar. 14, 1916
MANGOLD, JOHN FREDERIC. Asst. Prof. of Eng., Grinnell Coll.; City Engr., Box 84, Grinnell, Iowa		Dec. 6, 1915
MENGEL, CARL WAYNE. Engr.-in-Chg., Land Reclamation Dept., John L. Roper Lumber Co., Belhaven, N. C.	Jun. Assoc. M.	April 2, 1913 Mar. 14, 1916
O'ROURKE, BERNARD JOHN. Supt. of Constr., Dale Eng. Co., Utica, N. Y.		Mar. 14, 1916
PARKER, LAWRENCE GILBERT. Engr. in Chg. of Structural Dept., Marshall & Fox, 919 First National Bank Bldg., Chicago, Ill.		Mar. 14, 1916

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PLUMLEY, MARION STUART. Chf. Engr., Superior Oxygen Equipment Co., Pittsburgh (Res., 1429 Walnut St., Edgewood Park), Pa. .... Mar. 14, 1916

PURCELL, CHARLES HENRY. Multnomah County Bridge Engr., 1426 Alameda Drive, Portland, Ore. .... Mar. 14, 1916

ROBINSON, EUGENE WEBSTER. Engr., McKenzie Constr. Co., 504 Hunstock Ave., San Antonio, Tex. .... Mar. 14, 1916

ROLFE, ROBERT LAWRENCE. U. S. Engr. Office, Box 1027, Memphis, Tenn. .... Jun. Sept. 5, 1911; Assoc. M. Mar. 14, 1916

SALISBURY, ALFRED JAMES, JR. Chf. Engr., Imperial Water Co. No. 3, Calipatria, Cal. .... Mar. 14, 1916

SAVILLE, ALLEN JETER. Engr. and Contr. (Saville & Claiborne), 205 Real Estate Exchange Bldg., Richmond, Va. .... Mar. 14, 1916

SCHENSTROM, WILHELM ROLF OSCAR HOLMBOE. Vice-Pres. and Contr. Engr., Elec. Welding Co., 220 West 42d St., New York City .... Mar. 14, 1916

SEELY, RAY. County Engr., Lake County, Hammond, Ind. Mar. 14, 1916

SEWARD, OSCAR A., JR. Asst. City Engr., Beaumont, Tex.. Mar. 14, 1916

SHEIBLEY, EDWARD GWYN. Engr., Southwestern Portland Cement Co., El Paso, Tex. .... Mar. 14, 1916

SMITH, FRANCIS MARSHALL. Trainmaster, N. P. Ry., East Grand Forks, Minn. .... Jun. Jan. 3, 1907; Assoc. M. Dec. 6, 1915

STEWART, SPENCER WILSON. Pres. and Chf. Engr., Stewart Eng. Corporation, 17 Battery Pl., New York City.. Mar. 14, 1916

TAYLOR, PRESLEY MORGAN. With the American Volunteer Motor Ambulance Corps, Care, Brown, Shipley & Co., 123 Pall Mall, London, England .... Mar. 14, 1916

THOMPSON, LAURENCE KIMBALL. 817 West 23d St., Los Angeles, Cal. .... Mar. 14, 1916

WEBB, ISHAM GANO. Eng. Insp. and Asst. Supt. of Constr., Board of State Harbor Commrs., 2060 Ellis St., San Francisco, Cal. .... Mar. 14, 1916

WRIGHT, JESSE CLARK. Engr., Mercereau Bridge & Constr. Co., 471 Pacific Elec. Bldg., Los Angeles, Cal. .... Mar. 14, 1916

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MITCHELL, LOUIS. Associate Prof. of Civ. Eng., Syracuse Univ., 604 Comstock Ave., Syracuse, N. Y. .... Mar. 14, 1916

ROBBINS, ARTHUR GRAHAM. Prof. of Topographical Eng., Mass. Inst. Tech., Boston, Mass. .... Mar. 14, 1916

JUNIORS

BELL, VICTOR HUGO. (Bell & Larson), P. O. Box 12, Calexico, Cal. .... Mar. 14, 1916

CARSON, HARRY YOUNG. San. Engr., The Central Foundry Co., 90 West St., New York City .... Mar. 14, 1916

JUNIORS (*Continued*)	Date of Membership.
CEBRIAN, HARRY DE LAVEAGA. 176 Huntington Ave., Boston, Mass.	Mar. 14, 1916
DANZILLI, ALFRED MICHAEL. 807 Curry Bldg., Pittsburgh, Pa.	Jan. 17, 1916
ELLISON, ALEXANDER HALL. Sales Engr., Clyde Iron Works, Duluth, Minn.	Mar. 14, 1916
HAPGOOD, FREDERIC HERBERT. Y. M. C. A., Holyoke, Mass.	Mar. 14, 1916
IGNELZI, PLINIO. Draftsman, M. of W. Dept., Allegheny Div., P. R. R., 145 Meadow St., Pittsburgh, Pa.	Mar. 14, 1916
OLERI, FRANK JOHN. Junior Asst. Engr., Public Service Comm., 27 Catharine St., New York City	Mar. 14, 1916
OWEN, BARTRAM ASHMEAD. Draftsman, Sewage Disposal Div., Bureau of Surveys, City of Philadelphia, 411 Pine St., Philadelphia, Pa.	Mar. 14, 1916
TIDD, HARRY. Cons. Engr. (Pike-Tidd Eng. Co.), 416 Scarritt Bldg., Kansas City, Mo.	Mar. 14, 1916
WAITE, EARLE CHESTER. Structural Engr., Bethlehem Steel Co., 924 North 7th St., Allentown, Pa.	Mar. 14, 1916

CHANGES OF ADDRESS

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FISHER, SAMUEL BROWNLEE. Cons. Engr., M., K. & T. Ry., Parsons, Kans.

FOSS, WILLIAM EVERETT. Acting Chf. Engr., Met. Water-Works, 1 Ashburton Pl., Boston, Mass.

FRAZIER, JAMES WELCH. Pres., Frazier-Sheal Co., 1223 Illuminating Bldg., Cleveland, Ohio.

GAY, FREDERICK WALDO. Mech. Engr., J. G. White Eng. Corporation, 310 Sansome St., San Francisco, Cal.

GAYOL, ROBERTO. Cons. Engr., San Salvador, Salvador.

HANCOCK, ROBERT RIVES. Vice-Pres., The Philippine Ry., Iloilo, Philippine Islands.

HAND, FRANKLIN CLARK. Purcell, Okla.

HANSEN, PAUL. Chf. San. Engr., State Board of Health, Springfield, Ill.

HARKNESS, GEORGE EDWARD. Civ. Engr., Holbrook, Cabot & Rollins, 6 Beacon St., Boston, Mass.

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HOYT, WARREN ALBERT. Cons. and Contr. Engr., Altoona, Pa.

HUBBARD, FRANK RICHARDS. Mgr., Hawkeye Eng. Co., 421 Hubbell Bldg., Des Moines, Iowa.

HUFF, CLYDE LESLIE. Mio, Mich.

JAQUES, WILLIAM HENRY. Pres., Hampton Water-Works Co., Little Boar's Head, N. H.

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MACVICAR, JOHN DUNCAN. Asst. Chf. Engr.; C. & O. C. R. R., Grants Pass, Ore.

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Vent, Frederick Goodman. Designer, Dept. of Bridge Eng., Ill. Cent. R. R., Chicago, Ill.

Vose, Richard Hampton. Care, Robert W. Hunt & Co., 2200 Insurance Exchange, Chicago, Ill.

Whistler, John T. Engr., U. S. Reclamation Service, Tramway Bldg., Denver, Colo.

Winslow, Frederic Irving. Engr. of Extension, Public Works Dept., Water Service, 66 Bloomfield St., Dorchester, Mass.

ASSOCIATE MEMBERS

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HARTRIDGE, EARLE MENELAS. Hotel Aberdeen, New York City.

HATCH, EVERETT HAMILTON. 1508 Oxford St., Berkeley, Cal.

HAWN, RUSSELL JOHN. Mgr., Ohio Chemical Co., Springfield, Ohio.

HOLMES, HOWARD WHITTIER. Designing and Cons. Engr., 815 Northwestern Bank Bldg., Portland, Ore.

HUBBARD, DANIEL. Care, M. of W., B. & O. R. R., Cincinnati, Ohio.

HUGHES, WILLIAM RICHARD, JR. Gen. Contr. (Hughes-Foulkrod Co.), 1409 Commonwealth Trust Bldg., Philadelphia, Pa.

HYATT, CALEB. Engr. and Contr., 100 Broadway, New York City.

JACOBS, SELWYN SIMON. Care, James Stewart & Co., Inc., Box 556, Norfolk, Va.

JOUINE, GEORGES PIERRE FERDINAND. Brig. au 58eme d'Artillerie, 102eme Batterie de 58, Secteur Postal 57, France.

KINGSLEY, CHARLES BROWN. Gen. Mgr., Cement-Gun Co., Inc., 30 Church St., New York City (Res., 13 Hanford Pl., Caldwell, N. J.).

ASSOCIATE MEMBERS (*Continued*)

KIRKHAM, JOHN EDWARD. Ames, Iowa.

KNIGHT, WALTER JOSEPH. Pres., W. J. Knight Eng. & Contr. Co., 815 Wainwright Bldg., St. Louis, Mo.

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ONDERDONK, ARTHUR. Asst. Engr., United Fruit Co., Tela, Honduras.

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PIERCE, GEORGE ABEL. Care, Valuation Dept., N. Y. C. R. R., Crown Bldg., Cleveland, Ohio.

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ROCKWELL, SELDEN EMMETT. Care, Cleveland & Cameron, 1001 Rogers Bldg., Vancouver, B. C., Canada.

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SANGER, WALTER MAX. Care, Willys-Overland Co., 635 Lincoln Ave., Toledo, Ohio.

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SHEPPERD, THOMAS SHACKELFORD. Apartado Postal No. 512, Montevideo, Uruguay.

ASSOCIATE MEMBERS (*Continued*)

Slayton, Charles Albert. Fort Lauderdale, Fla.

Sloan, Norton Quincy. Care, Frank Hill Smith, Inc., 120 Broadway, New York City.

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Soper, Ellis Clark. Mech. Engr., Oficios 24, Havana, Cuba.

Sovereign, Harry Evans. Care, E. Denike, Laredo, Tex.

Spalding, Walter James. Asst. Engr., Municipal Dept., Ancon, Canal Zone, Panama.

Spencer, Paul Bertram. Div. Engr., Constr. Dept., N. Y., N. H. & H. R. R., 209 Pequot Ave., New London, Conn.

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Turner, Augustus Miesse. Dist. Engr. in Chg. of Track Elevation, C., C., C. & St. L. Ry., Columbus, Ohio.

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Walker, Edward Lloyd. Asst. Engr., Fay, Spofford & Thorndike, Boston, Mass.

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Whitcraft, Lewis Norris. Chf. Engr., Hydrated Lime Bureau of the National Lime Mfrs. Assoc., 26 Vanderbeek Pl., Hackensack, N. J.

White, Byron Ellsworth. Engr., Utica Gas & Elec. Co., 222 Genesee St. (Res., 1019 Steuben St.), Utica, N. Y.

Wilson, Harry Percival. 11 Shirley St., Worcester, Mass.

Wood, Robert Lee. Care, Supt., Iron Mt. Ry., Monroe, La.

Wright, Francis Herbert. 229 Goliad St., San Antonio, Tex.

JUNIORS

Alger, Ralph Tisdale. Asst. Engr., City of Akron Water-Works, 436 West Exchange St., Akron, Ohio.

Ayres, Quincy Claude. U. S. Junior Drainage Engr., 515 Fourteenth St., N. W., Washington, D. C.

Bailey, Clifton George. Sub-inspector, Public Works Dept., U. S. Naval Station, Key West, Fla.

Battie, Herbert Scandlin. P. O. Box 265, Greensboro, N. C.

Beerbower, Dumont. Valuation Dept., N. Y. C. R. R., Crown Bldg., Cleveland, Ohio.

Bley, Charles Nicholas. 2107 Hearst Ave., Berkeley, Cal.

Bryson, Carlyle Hugo. City Engr., Lima, Ohio.

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Carpenter, Sinclair Ernest. 1630A 3d Ave., Oakland, Cal.

Cook, Holton. Alcoa, Tenn.

Dunshee, Bertram Kellogg. 328 East Micheltorena St., Santa Barbara, Cal.

Edwards, Raymond Arden. 185 Dolores St., San Francisco, Cal.

Harrah, Orin Wilson. Junior Engr., U. S. Reclamation Service, Nashua, Mont.

Helmstetter, George Alfred. Park Engr., Syracuse Park Comm., City Hall, Syracuse, N. Y.

Jones, Charles Hyland. 20 Broad St., New York City.

Kable, George Wallace. Deming, N. Mex.

Kohn, Arthur Hirsh. 505 Eighth Ave., Brooklyn, N. Y.

Le Grand, Joseph Mastella. Care, Canadian Copper Co., Copper Cliff, Ont., Canada.

Lehman, Henry Maron. 50 Court St., Room 1009, Brooklyn, N. Y.

Lovering, Harry Douglas. Asst. Supt. and Civ. Engr., Hodgin Const. Co., 1464 Summit Ave., St. Paul, Minn.

Merritt, Charles Edward. Civ. Engr. and Contr., 133 Genesee St., New Hartford, N. Y.

Mills, Guy G. Eng. Dept., Assoc. of Am. Portland Cement Mfrs., 111 West Washington St., Chicago, Ill.

Parsons, Maurice Giesy. 910 South Madison Ave., Pasadena, Cal.

Perrin, Lester William. Care, Westinghouse, Church, Kerr & Co., 37 Wall St., New York City.

Rhodes, Eric Houghton. Ronaki, Remuera, Auckland, New Zealand.

Stallings, John Robert. Asst. Engr., E. A. Kingsley Eng. Co., Care, Y. M. C. A., Little Rock, Ark.

Strandberg, George Robert. 616 Fifth St., Bremerton, Wash.

Street, John Zadok. 315 Lincoln Ave., New Castle, Pa.

Swinton, Roy Stanley. Instr., Eng. Mech., Univ. of Michigan, 1313 Geddes Ave., Ann Arbor, Mich.

Thackwell, Henry Lawrence. Engr. and Mgr., Uinta County Irrig. Co., Marbleton, Wyo.

JUNIORS (*Continued*)

VAN NESS, RUSSELL ALGER. 914 Karpen Bldg., Chicago, Ill.

WAGNER, JOHN, JR. Structural Draftsman, P. R. R., Broad St. Station, Philadelphia, Pa.

WAY, WILLIAM FLOYD. Care, Alaskan Eng. Comm., Seward, Alaska.

WHITNEY, CHARLES SMITH. 1120 South Grand Ave., Los Angeles, Cal.

WILSON, EMMET CHEATHAM. With Virginia Bridge & Iron Co., 1202 Jefferson St., Roanoke, Va.

DEATHS

CRAWFORD, GEORGE LENOX. Elected Associate Member, September 3d, 1912; died February 3d, 1916.

DUNN, DANIEL BURKE. Elected Member, December 2d, 1891; died March 18th, 1916.

FITCH, ASA BETTS. Elected Member, March 5th, 1884; died March 11th, 1916.

GILFILLAN, GEORGE AIKEN. Elected Member, December 6th, 1905; died March 13th, 1916.

GRIMM, CARL ROBERT. Elected Member, June 4th, 1890; died February 15th, 1916.

HOYT, WILLIAM EDWIN. Elected Member, March 5th, 1884; died April 2d, 1916.

LEAVITT, ERASMUS DARWIN. Elected Member, July 2d, 1873; died March 11th, 1916.

PARTHESIUS, PHILIP HENRY. Elected Associate Member, November 1st, 1910; died February 16th, 1915.

SHAW, WILLIAM THOMAS. Elected Associate Member, June 30th, 1910; date of death unknown.

SMITH, WILLIAM SOOY. Elected Member, January 17th, 1872; died March 4th, 1916.

VAUGHN, GEORGE WASHINGTON. Elected Member, June 3d, 1891; died February 3d, 1916.

VOORHEES, THEODORE. Elected Member, May 6th, 1885; died March 12th, 1916.

WARNER, JAMES MADISON. Elected Junior, April 6th, 1909; Associate Member, December 3d, 1913; died March 9th, 1916.

WOODBURY, CHARLES JEPTHA HILL. Elected Member, December 3d, 1884; died March 20th, 1916.

WROTNOWSKI, ARTHUR FRANCIS. Elected Member, July 12th, 1877; date of death unknown.

Total Membership of the Society, April 6th, 1916,

7 938.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST

(February 28th, to April 1st, 1916)

NOTE.—*This list is published for the purpose of placing before the members of this Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS

In the subjoined list of articles, references are given by the number prefixed to each journal in this list:

(2) *Proceedings,* Engrs. Club of Phila., Philadelphia, Pa.
(3) *Journal,* Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal,* Western Soc. of Engrs., Chicago, Ill., 50c.
(5) *Transactions,* Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly,* Columbia Univ., New York City, 50c.
(7) *Gesundheits Ingenieur,* München, Germany.
(8) *Stevens Institute Indicator,* Hoboken, N. J., 50c.
(9) *Engineering Magazine,* New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, 432 Fourth Ave., New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News,* New York City, 15c.
(14) *Engineering Record,* New York City, 10c.
(15) *Railway Age Gazette,* New York City, 15c.
(16) *Engineering and Mining Journal,* New York City, 15c.
(17) *Electric Railway Journal,* New York City, 10c.
(18) *Railway Review,* Chicago, Ill., 15c.
(19) *Scientific American Supplement,* New York City, 10c.
(20) *Iron Age,* New York City, 20c.
(21) *Railway Engineer,* London, England, 1s. 2d.
(22) *Iron and Coal Trades Review,* London, England, 6d.
(23) *Railway Gazette,* London, England, 6d.
(24) *American Gas Light Journal,* New York City, 10c.
(25) *Railway Mechanical Engineer,* New York City, 20c.
(26) *Electrical Review,* London, England, 4d.
(27) *Electrical World,* New York City, 10c.
(28) *Journal,* New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal,* Royal Society of Arts, London, England, 6d.
(30) *Annales des Travaux Publics de Belgique,* Brussels, Belgium, 4 fr.
(31) *Annales* de l'Assoc. des Ing. Sortis des Ecoles Spéciales de Gand, Brussels, Belgium, 4 fr.
(32) *Mémoires et Compte Rendu des Travaux,* Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil,* Paris, France, 1 fr.
(34) *Portefeuille Economiques des Machines,* Paris, France.
(35) *Nouvelles Annales de la Construction,* Paris, France.
(36) *Cornell Civil Engineer,* Ithaca, N. Y.
(37) *Revue de Mécanique,* Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways,* Paris, France.
(39) *Technisches Gemeindeblatt,* Berlin, Germany, 0, 70m.
(40) *Zentralblatt der Bauverwaltung,* Berlin, Germany, 60 pfg.
(41) *Electrotechnische Zeitschrift,* Berlin, Germany.
(42) *Proceedings,* Am. Inst. Elec. Engrs., New York City, $1.
(43) *Annales des Ponts et Chaussées,* Paris, France.
(44) *Journal,* Military Service Institution, Governors Island, New York Harbor, 50c.
(45) *Coal Age,* New York City, 10c.
(46) *Scientific American,* New York City, 15c.
(47) *Mechanical Engineer,* Manchester, England, 3d.
(48) *Zeitschrift,* Verein Deutscher Ingenieure, Berlin, Germany, 1, 60m.
(49) *Zeitschrift für Bauwesen,* Berlin, Germany.
(50) *Stahl und Eisen,* Düsseldorf, Germany.
(51) *Deutsche Bauzeitung,* Berlin, Germany.
(52) *Rigasche Industrie-Zeitung,* Riga, Russia, 25 kop.
(53) *Zeitschrift,* Oesterreichischer Ingenieur und Architekten Verein, Vienna, Austria, 70h.
(54) *Transactions,* Am. Soc. C. E., New York City, $12.
(55) *Transactions,* Am. Soc. M. E., New York City, $10.
(56) *Transactions,* Am. Inst. Min. Engrs., New York City, $6.

(57) *Colliery Guardian,* London, England, 5d.
(58) *Proceedings,* Engrs.' Soc. W. Pa., 2511 Oliver Bldg., Pittsburgh, Pa., 50c.
(59) *Proceedings,* American Water-Works Assoc., Troy, N. Y.
(60) *Municipal Engineering,* Indianapolis, Ind., 25c.
(61) *Proceedings,* Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *Steel and Iron,* Thaw Bldg., Pittsburgh, Pa., 10c.
(63) *Minutes of Proceedings,* Inst. C. E., London, England.
(64) *Power,* New York City, 5c.
(65) *Official Proceedings,* New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting,* London, England, 6d.
(67) *Cement and Engineering News,* Chicago, Ill., 25c.
(68) *Mining Journal,* London, England, 6d.
(69) *Der Eisenbau,* Leipzig, Germany.
(71) *Journal,* Iron and Steel Inst., London, England.
(71*a*) *Carnegie Scholarship Memoirs,* Iron and Steel Inst., London, England.
(72) *American Machinist,* New York City, 15c.
(73) *Electrician,* London, England, 18c.
(74) *Transactions,* Inst. of Min. and Metal., London, England.
(75) *Proceedings,* Inst. of Mech. Engrs., London, England.
(76) *Brick,* Chicago, Ill., 20c.
(77) *Journal,* Inst. Elec. Engrs., London, England, 5s.
(78) *Beton und Eisen,* Vienna, Austria, 1, 50m.
(79) *Forschcrarbeiten,* Vienna, Austria.
(80) *Tonindustrie Zeitung,* Berlin, Germany.
(81) *Zeitschrift für Architektur und Ingenieurwesen,* Wiesbaden, Germany.
(82) *Mining and Engineering World,* Chicago, Ill., 10c.
(83) *Gas Age,* New York City, 15c.
(84) *Le Ciment,* Paris, France.
(85) *Proceedings,* Am. Ry. Eng. Assoc., Chicago, Ill.
(86) *Engineering-Contracting,* Chicago, Ill., 10c.
(87) *Railway Engineering and Maintenance of Way,* Chicago, Ill., 10c.
(88) *Bulletin* of the International Ry. Congress Assoc., Brussels, Belgium.
(89) *Proceedings,* Am. Soc. for Testing Materials, Philadelphia, Pa., $5.
(90) *Transactions,* Inst. of Naval Archts., London, England.
(91) *Transactions,* Soc. Naval Archts. and Marine Engrs., New York City.
(92) *Bulletin,* Soc. d'Encouragement pour l'Industrie Nationale, Paris, France.
(93) *Revue de Métallurgie,* Paris, France, 4 fr. 50.
(95) *International Marine Engineering,* New York City, 20c.
(96) *Canadian Engineer,* Toronto, Ont., Canada, 10c.
(98) *Journal,* Engrs. Soc. Pa., Harrisburg, Pa., 30c.
(99) *Proceedings,* Am. Soc. of Municipal Improvements, New York City, $2.
(100) *Professional Memoirs,* Corps of Engrs., U. S. A., Washington, D. C., 50c.
(101) *Metal Worker,* New York City, 10c.
(102) *Organ für die Fortschritte des Eisenbahnwesens,* Wiesbaden, Germany.
(103) *Mining Press,* San Francisco, Cal., 10c.
(104) *The Surveyor and Municipal and County Engineer,* London, England, 6d.
(105) *Metallurgical and Chemical Engineering,* New York City, 25c.
(106) *Transactions,* Inst. of Min. Engrs., London, England, 6s.
(107) *Schweizerische Bauzeitung,* Zürich, Switzerland.
(108) *Iron Tradesman,* Atlanta, Ga., 10c.
(109) *Journal,* Boston Soc. C. E., Boston, Mass., 50c.
(110) *Journal,* Am. Concrete Inst., Philadelphia, Pa., 50c.
(111) *Journal of Electricity, Power and Gas,* San Francisco, Cal., 25c.
(112) *Internationale Zeitschrift für Wasser-Versorgung,* Leipzig, Germany.
(113) *Proceedings,* Am. Wood Preservers' Assoc., Baltimore, Md.
(114) *Journal,* Institution of Municipal and County Engineers, London, England, 1s. 6d.
(115) *Journal,* Engrs.' Club of St. Louis, St. Louis, Mo., 35c.

LIST OF ARTICLES

Bridges.

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Failure of Penistone Viaduct.* (12) Feb. 11.
New Bridge Over the Ribble at Preston.* (12) Feb. 18.
A Swing Bridge at Newport, Isle of Wight.* E. A. Slater. (104) Feb. 18.
The Largest Cantilever Bridge in the World.* (87) Mar.
Simple Type of Concrete Bridge for Grade Crossings.* C. W. Martin. (13) Mar. 2.
Pine Bluff Vertical-Lift Span Suspended by Chains.* (13) Mar. 2.
New Formulas for Weights of Girders and Trusses. A. G. Hayden. (13) Mar. 2.

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* Illustrated.

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Building Concrete Piers for Sciotoville Bridge.* (13) Mar. 2.
Glebe Island Bridge, Port Jackson, New South Wales.* (11) Mar. 3.
Design of Masonry and Concrete Arches.* R. J. Williams. (104) Mar. 3.
Great Variety in Design Reduces Cost of New Portland Harbor Bridge. (14) Mar. 4.
Half of Long Steel Viaduct at Cleveland Wrecked in Seven Days.* (14) Mar. 4.
Strengthening the Cairo Bridge on Illinois Central R. R.* (13) Mar. 9.
Special Steel and Timber Erection Tower Places Heavy Plate Girders.* (14) Mar. 11.
Brooklyn-Brighton Concrete Viaduct Completed.* W. H. Baker. (13) Mar. 16.
New Susquehanna River Bridge at Harrisburg, Cumberland Valley R. R.* (15) Mar. 17.
Minnesota Commission Adopts Clearances.* (14) Mar. 18.
Corpus Christi Causeway Contains 2 300 Feet of Reinforced-Concrete Girder Spans.* Terrell Bartlett. (14) Mar. 18.
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Construction Progress on the Bloor Street Viaduct, Toronto, Canada. (From *The Concrete Record.*) (86) Mar. 22.
Light Wood Floor for Bridges.* (13) Mar. 23.
Susquehanna Concrete Viaduct Built in Halves.* (13) Mar. 23.
Lackawanna Improvements at South Orange.* A. B. Cohen. (15) Mar. 24.
Rusted Pony Truss Collapses at Johnstown, Penn.* (13) Mar. 30.
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Four-Span Steel-Arch Bridge at Indianapolis, Ind.* (13) Mar. 30.
Strachan Avenue Bridge, Toronto.* E. M. Proctor. (96) Mar. 30.
Considérations sur les Ponts Tournants sur Pile Centrale.* E. Boucher. (33) Feb. 19.
Bogenbrücken aus umschnürtem Gusseisenbeton.* H. Nitzsche. (51) Sup. 5, 1915.
Die Ohio-River-Brücke zu Sciotoville.* J. Melan. (69) Dec., 1915.
Kontinuierliche Träger auf 4, 5 und 6 Stützen unter Verteilten und Einzellasten.* H. Nitzsche. (69) Dec., 1915.
Belastungsannahmen für Strassenbrücken und Vorschläge für ihre Vereinheitlichung.* H. Kayser. (49) Pt. 1.
Riss- und Rostbildung bei ausgeführten Eisenbetonbrücken der Eisenbahndirektionsbezirke Kattowitz und Breslau. Perkuhn. (49) Pt. 1.
Die Waldeckbrücke bei Burgdorf.* M. Schnyder. (107) Feb. 26.

Electrical.

The Hydro-Electric Development of the Peninsular Power Co.* Charles V. Seastone. (56) Vol. 51, 1915.
Selenium Cells.* W. R. Cooper. (73) Serial beginning Feb. 11.
The Equipment and Protection of Outdoor H. T. Sub-Stations. J. Lindley Thompson and S. Austen Stigant. (73) Feb. 11.
Union Central Building Power-Plant Tests.* C. B. Garrison. (64) Feb. 15.
The Principles of Modern Printing Telegraphy.* H. H. Harrison. (77) Feb. 15.
Characteristics of Three-Phase Induction Motors on Single-Phase Circuits.* M. Rosenbaum. (73) Feb. 18.
Federal Power Development at Williston.* A. P. Connor. (64) Feb. 22.
The Effect of Electric Oscillations on the Magnetic Properties of Iron Investigated by the Campograph.* J. A. Fleming and P. R. Coursey. (Abstract of paper read before the Physical Soc.) (73) Feb. 25.
Increasing the Traffic Capacity of Telegraph Lines by Acoustic Tuning.* (26) Feb. 25.
Parallel Operation of Direct-Current Generators.* Alan M. Bennett. (64) Serial beginning Feb. 29.
Relative Value of Private and Purchased Electric Power for Textile Mills.* F. W. Reynolds and Dan Adams. (72) Mar.
The Influence of Frequency of Alternating or Infrequently Reversed Current on Electrolytic Corrosion.* Burton McCollum and G. H. Ahlborn. (42) Mar.
Iron Losses in Direct-Current Machines.* B. G. Lamme. (42) Mar.
Apparatus for Starting and Controlling Electrical Running Machinery.* C. C. Garrard. (73) Mar. 3.
Tests on Oil Switches.* Bruno Bauer. (*Bulletin No. 5*, Schweizer Elektrotechn. Verein.) (73) Mar. 3.
A Variable Speed Transmission Gear.* (73) Mar. 3.
The Insulation of Joints in High Tension Cables.* (27) Mar. 4.
Laying Submarine Cables Across the Golden Gate.* (27) Mar. 4.
Remington Arms & Ammunition Company's Power Plant.* Warren O. Rogers. (64) Mar. 7.
Some Recent Developments in the Audion Receiver.* Edwin H. Armstrong. (Paper read before the Inst. of Radio Engrs.) (73) Mar. 10.
The Renaissance of the Low-Tension Fuse.* John A. Crabtree. (26) Serial beginning Mar. 10.

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* Illustrated.

Electrical—(Continued).

Electric Lifts. H. Marryat. (Abstract of paper read before the Assoc. of Supervising Electricians.) (47) Serial beginning Mar. 10.
Uniformity in Drawing Electrical Diagrams. Gisbert Kapp. (73) Mar. 10.
Performance of Diesel-Engine Plants in Texas.* R. H. Burdick. (27) Mar. 11.
The Regulation of Direct-Current Generators. H. M. Phillips. (64) Mar. 14.
Serving an 8 500 Hp. Steel Rolling Mill Load.* (27) Mar. 18.
Milwaukee's Extensive Street-Lighting Plan.* (27) Mar. 18.
A Source of Error When Using the Sphere Gap. R. H. Marvin. (27) Mar. 18.
Design of Darien Radio Towers.* C. A. Carlson. (13) Mar. 23.
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Unit Design in Marine Wireless Telegraphy. J. Andrew White. (46) Mar. 25.
Manufacture of Punchings. C. W. Starker. (72) Mar. 30.
Service Requirements of the Electric Arc Furnace.* Harry Hollis. (27) Apr. 1.
Minimizing Electrolysis of Cable Sheaths.* (27) Apr. 1.
Street Lighting on a Cost-of-Service Basis. G. W. Van Derzee. (27) Apr. 1.
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Les Récents Perfectionnements dans les Compteurs d'Electricité. (33) Mar. 4.
Die Verwertung der Walchensee-Wasserkraft für ein Bayernwerk.* Oskar von Miller. (41) Serial beginning Feb. 17.
Messung sehr hoher Isolationswiderstände von Kabeln. J. Fischer-Hinnen. (41) Feb. 24.
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Der Einfluss von Isolationsfehlern auf Ableitungs—und Kapazitätsströme bei Dreiphasen—Fernleitungen mit und ohne Schutzseil.* H. Behrend. (41) Mar. 2.
Elektrisch geheizte Laboratoriumsofen für hohe Temperaturen.* K. Arndt. (41) Mar. 2.
Stromregelung beim Diathermieapparat.* H. Fassbender. (41) Mar. 9.
Ueberströme und Ueberspannungen in Netzen mit hohem Erdschlussstrom.* W. Petersen. (41) Mar. 9.

Marine.

Spanish Torpedo-Boat Destroyers of the *Bustamante* Class.* (11) Serial beginning Feb. 11.
Heat Maladies of Marine Engines. R. W. Crowly. (64) Feb. 22.
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PAPERS AND DISCUSSIONS

APRIL, 1916

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AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

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AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

THE DESIGN OF A DRIFT BARRIER ACROSS WHITE RIVER, NEAR AUBURN, WASHINGTON

By H. H. Wolff, M. Am. Soc. C. E.

To be Presented May 3d, 1916.

Synopsis.

The purpose of this paper is to describe a structure, believed to be unique, for eliminating, from the upper reaches of a mountain stream, large quantities of drift, the accumulation of which in the lowlands had been causing much damage.

Before beginning a description of the drift barrier, a short outline of the project, of which it is a part, and the conditions which made its construction necessary, may not be amiss.

White River is one of the mountain streams of Western Washington, and derives its waters in part from the Cascades and in part from the glaciers of Mount Rainier. It runs to tide-water in Puget Sound, and in flood period is an exceptionally violent torrent, even for a mountain stream. The lower reaches of the river pass through a number of villages and through land of the highest agricultural value, and most of this land, on account of its sedimentary or alluvial nature, offers

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

very little resistance to erosion. The upper portion runs through very heavy timber, and in times of flood the water erodes the banks and carries with it large numbers of trees, saw-logs, stumps, and down timber, as drift.

The damage done in the past and the danger of greater damage in the future induced the authorities of King and Pierce Counties to undertake jointly the control and rectification of the river. The main features of the project include straightening the channel by dredging and otherwise, bank protection of various types, and a drift barrier. The work is being done under W. J. Roberts, M. Am. Soc. C. E., as Chief Engineer.

It will be seen from Fig. 1 that the river has deviated greatly from the shortest course, the normal bed, and in places has covered considerable areas, cutting away the land and leaving gravel bars below flood level. A close study of conditions shows that in every instance the current was first deflected by an accumulation of drift, the huge timber of this section serving readily in its formation.

Referring to the barrier site, where the river grade is 35 ft. per mile, drift begins running at about a 3-ft. stage of water. At the highest known stage, 9 ft., the quantity was very great, and the erosion of the banks, even in the upper reaches, very rapid, so that stumps from logged-off sections and full-grown trees were carried away. When one of these catches on an obstruction below, it quickly entangles others, and the mass of drift thus formed is solid enough to deflect the current.

Gravel, sand, and silt collect in the dead water, behind the drift piles, strengthening them and preventing the river from returning to its original bed. Evidences of this action are plentiful, and, in the narrow valley of the upper reaches, show that the river has been forced from the hills on one side to those of the other, a distance of ½ mile or more, and the original bed has become overgrown with very heavy timber.

It became essential, therefore, to erect some structure above the limit of the protective works and channel changes to eliminate or hold the drift and, after clearing the river from all drift lodged below or scattered along its bottom, prevent the accumulation of any more masses. The writer was entrusted by Mr. Roberts with the design and construction of such a barrier.

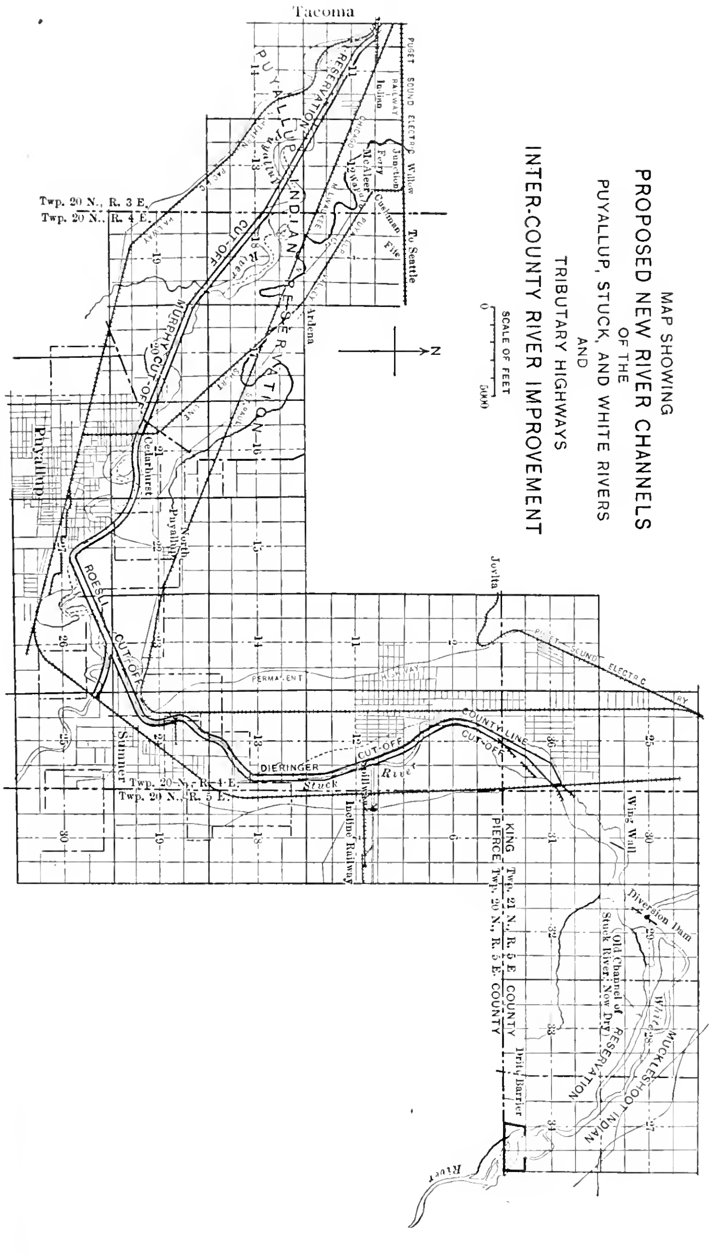

MAP SHOWING
PROPOSED NEW RIVER CHANNELS
OF THE
PUYALLUP, STUCK, AND WHITE RIVERS
AND
TRIBUTARY HIGHWAYS
INTER-COUNTY RIVER IMPROVEMENT
SCALE OF FEET
0
5000
N
Tacoma
To Seattle
PUGET SOUND ELECTRIC RAILWAY
Junction
Willow
Ferry
Cushman
Fife
Inlian
McAleer
Ardena
PUYALLUP INDIAN RESERVATION
MURPHY CUT-OFF
ROESLI CUT-OFF
DIERINGER CUT-OFF
COUNTY LINE CUT-OFF
Twp. 20 N., R. 3 E.
Twp. 20 N., R. 4 E.
Twp. 20 N., R. 5 E.
Puyallup
Cedarhurst
North Puyallup
Sumner
Jovita
PERMANENT HIGHWAY
Stuck River
Spillway
Incline Railway
Wing Wall
Diversion Dam
Old Channel of Stuck River, Now Dry
White
MUCKLESHOOT INDIAN RESERVATION
Drift Barrier
KING COUNTY
PIERCE COUNTY
Twp. 21 N., R. 5 E.
Twp. 20 N., R. 5 E.
River

FIG. 1.

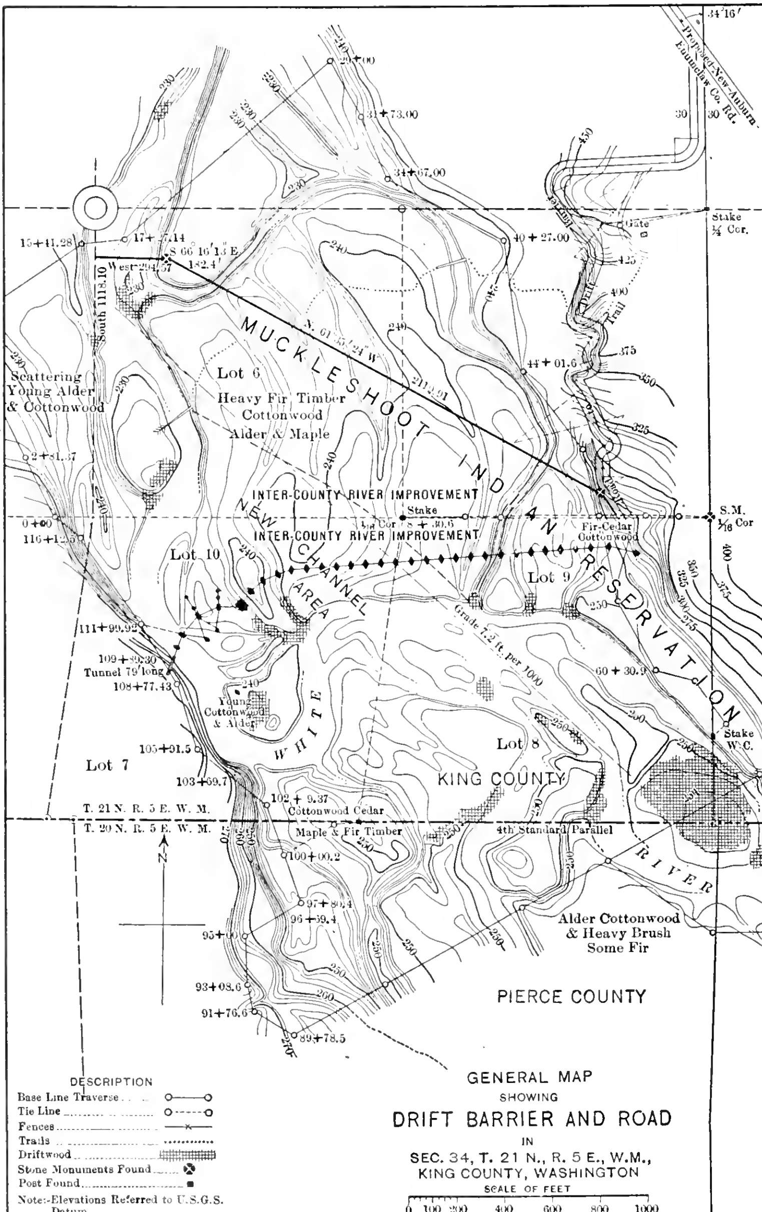

GENERAL MAP
SHOWING
DRIFT BARRIER AND ROAD
IN
SEC. 34, T. 21 N., R. 5 E., W.M.,
KING COUNTY, WASHINGTON
SCALE OF FEET
0 100 200 400 600 800 1000
DESCRIPTION
Base Line Traverse
Tie Line
Fences
Trails
Driftwood
Stone Monuments Found
Post Found
Note:-Elevations Referred to U.S.G.S. Datum
MUCKLESHOOT INDIAN RESERVATION
INTER-COUNTY RIVER IMPROVEMENT
NEW CHANNEL AREA
WHITE RIVER
KING COUNTY
PIERCE COUNTY
Lot 6
Heavy Fir Timber
Cottonwood
Alder & Maple
Lot 7
Lot 8
Lot 9
Lot 10
Scattering Young Alder & Cottonwood
Young Cottonwood & Alder
Cottonwood Cedar
Maple & Fir Timber
Alder Cottonwood
& Heavy Brush
Some Fir
Fir-Cedar
Cottonwood
T. 21 N. R. 5 E. W. M.
T. 20 N. R. 5 E. W. M.
4th Standard Parallel
Proposed New Auburn Enumclaw Co. Rd.
Grade 7.2 ft. per 1000
Drift Trail
Tunnel 79' long
South 1118.10
West 294.57
S 66° 16' 13" E. 182.4'
Stake 1/4 Cor.
S.M. 1/16 Cor
Stake W.C.
Gate

FIG. 2.

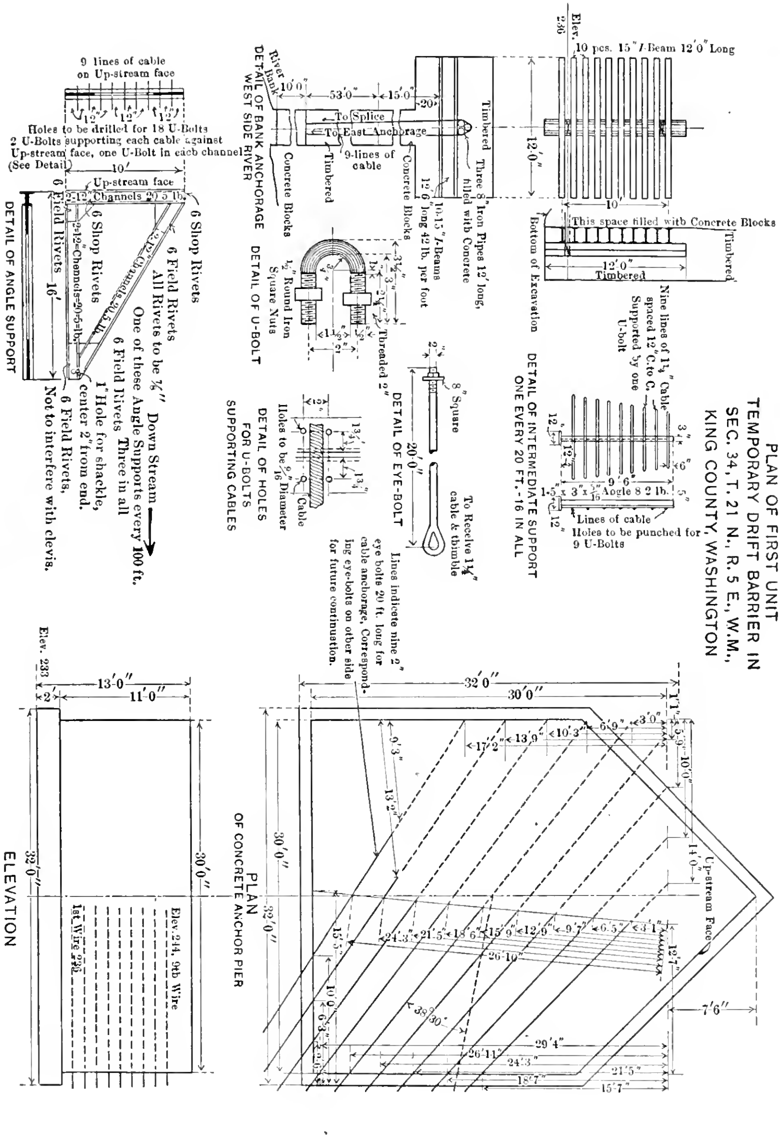

PLAN OF FIRST UNIT
TEMPORARY DRIFT BARRIER IN
SEC. 34, T. 21 N., R. 5 E., W.M.,
KING COUNTY, WASHINGTON
DETAIL OF INTERMEDIATE SUPPORT
ONE EVERY 20 FT.-16 IN ALL
DETAIL OF EYE-BOLT
DETAIL OF HOLES
FOR U-BOLTS
SUPPORTING CABLES
DETAIL OF BANK ANCHORAGE
WEST SIDE RIVER
DETAIL OF U-BOLT
DETAIL OF ANGLE SUPPORT
PLAN
OF CONCRETE ANCHOR PIER
ELEVATION

FIG. 3.

Choice of site was determined by shortness of distance across the valley and nearness to the protective work farthest up stream. The character of the valley, being practically the same within the limits of choice, did not influence it. The site is shown by Fig. 2 on an 80-acre tract bought by the Counties.

On account of delays in securing the land—which was in an Indian Reservation and bought through the Federal Government—it was impossible to begin construction before the middle of September, 1914. The severest floods have occurred between November 1st and 15th, and therefore it was imperative, in order to avoid danger of damage to improvements then being carried on below, to construct at once across the channel proper a temporary barrier, or a unit, which could be incorporated in the proposed permanent barrier extending across the entire valley, and of a type that could be built quickly.

Even for temporary purposes, a pile structure of any kind was not feasible, the river bottom being of compact gravel with large boulders which would have made it impossible to secure enough penetration.

The writer evolved the scheme of stretching cables across the entire flood channel, anchoring one set of ends in a high bank of indurated clay which was suitable for the purpose, the other in a concrete pier, and spacing the cables by spreaders placed at intervals across the channel. This design (Fig. 3) made possible the employment of a comparatively large number of men, and the rapid completion of essential portions on short warning of an impending flood. It also required little plant, and avoided the placing of main piers in the river proper, or in the flood channel.

The calculations were based on solid dam pressure, length equal to width of channel, and height 8 ft. Stresses were computed by suspension-bridge formulas, with deflection of cables one in four. Nine 1¼-in., 6 by 19 wire-rope cables, 1 ft. from center to center, were used, the lowest being 2 ft. above extreme low water. The bank anchorage is in the cross-cut of a narrow tunnel carried 80 ft. into the hill, and consists of three vertical 8-in. iron pipes, filled with concrete, bearing against ten horizontal 15-in. I-beams, 12 ft. long, which are 1 ft. from center to center and are separated by moulded concrete blocks. The I-beams bear against and are partly embedded in a block of concrete, filling a 2-ft. space between the I-beams and the wall and extending 13 ft. farther down the tunnel. The cables pass through a set of holes

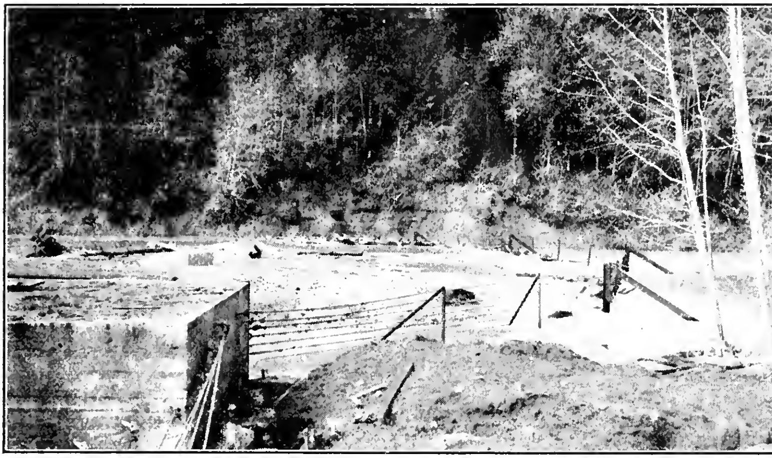


FIG. 4.—GENERAL VIEW OF FIRST UNIT LOOKING WEST DURING 3-FOOT STAGE OF WATER.

FIG. 5.—CONCRETE SUPPORT FOR TRIANGLES, FIRST UNIT, ANCHORAGE BLOCK IN BACKGROUND.

FIG. 8.—TYPICAL PIER, DRIFT BARRIER EXTENSION.

FIG. 9.—INTERMEDIATE WORK, DRIFT BARRIER EXTENSION.

FIG. 10.—NEW CHANNEL BETWEEN PIERS NOS. 11 AND 12 OF DRIFT BARRIER.

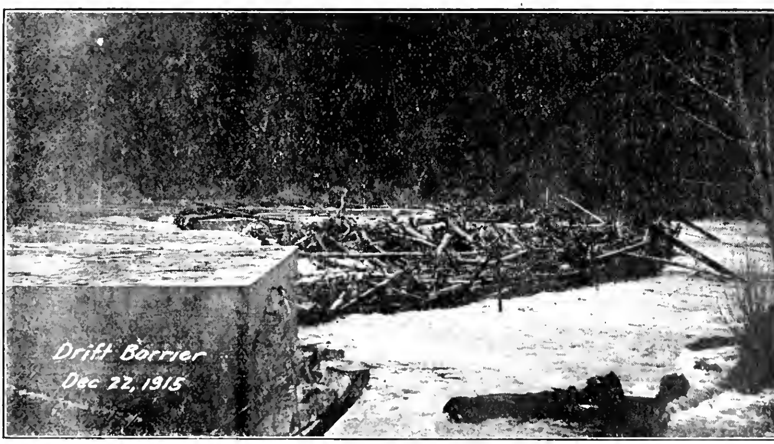
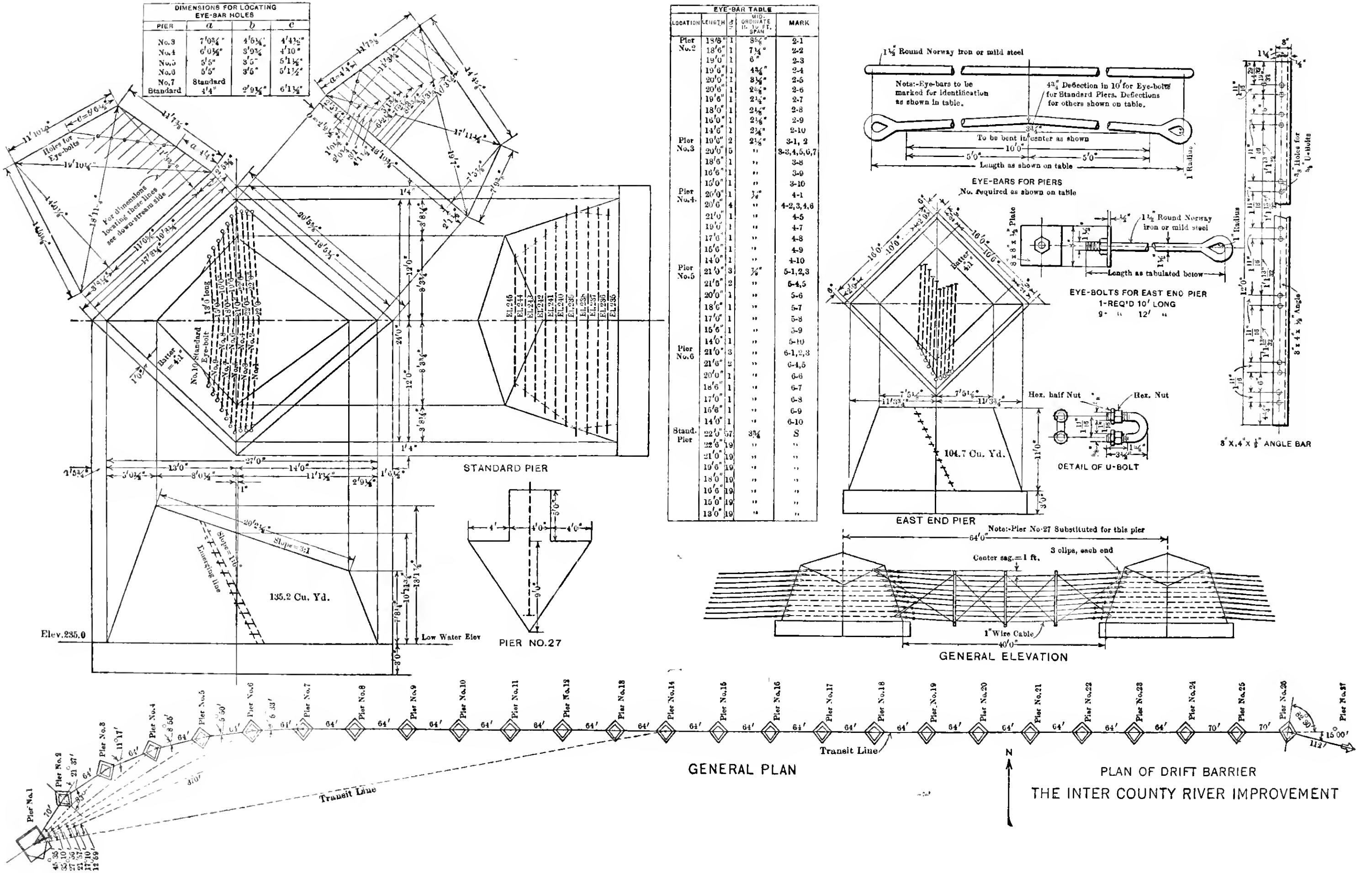


FIG. 11.—FIRST UNIT, LOOKING WEST, DURING FLOOD OF DECEMBER, 1915.

DIMENSIONS FOR LOCATING EYE-BAR HOLES			
PIER	*a*	*b*	*c*
No. 3	7'0¾"	4'5¼"	4'4½"
No. 4	6'0½"	3'9¾"	4'10"
No. 5	5'5"	3'5"	5'1½"
No. 6	5'5"	3'5"	5'1½"
No. 7 Standard	Standard 4'4"	2'9½"	6'1½"

EYE-BAR TABLE				
LOCATION	LENGTH	No.	MID-ORDINATE IN 10 FT. SPAN	MARK
Pier No. 2	18'8"	1	8⅝"	2-1
	18'6"	1	7¼"	2-2
	19'0"	1	6"	2-3
	19'6"	1	4¾"	2-4
	20'0"	1	3⅛"	2-5
	20'6"	1	2⅝"	2-6
	19'6"	1	2¼"	2-7
	18'0"	1	2⅛"	2-8
	16'0"	1	2⅛"	2-9
	14'6"	1	2¼"	2-10
Pier No. 3	19'6"	2	2⅛"	3-1, 2
	20'0"	5	"	3-3,4,5,6,7
	18'6"	1	"	3-8
	16'6"	1	"	3-9
	15'0"	1	"	3-10
Pier No. 4.	20'0"	1	⅛"	4-1
	20'6"	4	"	4-2,3,4,6
	21'0"	1	"	4-5
	19'0"	1	"	4-7
	17'6"	1	"	4-8
	15'6"	1	"	4-9
	14'0"	1	"	4-10
Pier No. 5	21'0"	3	⅛"	5-1,2,3
	21'6"	2	"	5-4,5
	20'0"	1	"	5-6
	18'6"	1	"	5-7
	17'0"	1	"	5-8
	15'6"	1	"	5-9
	14'0"	1	"	5-10
Pier No. 6	21'0"	3	"	6-1,2,3
	21'6"	2	"	6-4,5
	20'0"	1	"	6-6
	18'6"	1	"	6-7
	17'0"	1	"	6-8
	15'6"	1	"	6-9
	14'0"	1	"	6-10
Stand. Pier	22'0"	57	3¾	S
	22'6"	19	"	"
	21'0"	19	"	"
	19'6"	19	"	"
	18'0"	19	"	"
	16'6"	19	"	"
	15'0"	19	"	"
	13'0"	19	"	"



PLAN OF DRIFT BARRIER

THE INTER COUNTY RIVER IMPROVEMENT

left in the block, loop twice around the pipes, and pass back through another set of holes, beyond which the ends are fastened to the line with wire-rope clips. The end of the tunnel is sealed with a 10-ft. block of concrete with holes through which the cables pass. The intermediate portion is timbered, with 3 ft. between the posts. A gallery extends the full length of the tunnel above the cables and blocks, for inspection and renewal of cables.

The other anchorage is a block of concrete of 480 cu. yd., in which are embedded nine 2-in. eye-bars, 20 ft. long, to which the cables are attached. The arc of the cables is maintained through three triangles made of built I-beams which are anchored down stream to small concrete blocks. To the vertical face, which is up stream, the cables are fastened with U-bolts. They are supported by slabs of reinforced concrete, 1 ft. thick, with aprons in all directions on a 1 in 3 slope, but are not anchored to these. The intermediate spacers are 3 by 5-in. angles.

Two jam piers are set a short distance up stream, in order to break up any large masses of drift.

A small auxiliary pier with an anchored I-beam triangle was placed in the main channel to absorb the first impact of drift in the first flood and prevent excessive distortion of the line of cables.

After the fall flood period, the extension of the barrier across the valley was begun. The design adopted was based on the same general idea as the first unit, but was much modified in detail.

On the assumed data, as stated previously, the horizontal pressure to be taken up by the anchorages is 1 ton per lin. ft. This is irrespective of the length of span. Assuming a coefficient of friction of 0.5, the weight of concrete at 2 tons per cu. yd., and a safety factor of 2, it is evident that 3 488 cu. yd. are necessary for anchorages in the 1 744 lin. ft. of the extension, whether the spans are long or short. The size of the piers is proportionate to the length of the span. In order to make the spans self-supporting, and thereby eliminate intermediate supports, it was decided to make them as short as possible, within the limits of leaving ample waterway and of having sufficient yardage in each pier so that, with the height necessarily fixed by the number of cables, the design of the pier could be such as to keep the center of gravity low. A distance of 64 ft. from center to center of piers was adopted. Ten horizontal cables were used, and two for diagonal trussing. The horizontal cables were given a sag of 1 ft. in the center to allow a deflection of that much (or approximately 1 in 40) for the clear span. They are of 6 by 19 crucible-steel wire rope, 1 in. in diameter, and have an ultimate strength of 30 tons each. They are fastened with wire-rope clips to eye-bars of 1½-in. mild steel extending through the middle of the pier. The piers are diamond-shaped, and have a center height of 11 ft.; their tops have a slope of 1 in 3 in order to allow drift to ride up on them, and the sides are battered 4 in. to the foot. The details of the design are shown on Plate V.

The axial grade of the river at this point is 0.7%, which gives a grade of 0.4% along the line of the barrier.

The piers rest on a hard gravel and boulder foundation, evidently old river bottom, and are carried from 3 to 5 ft. below low-water grade.

It was not considered necessary to go below the scour line, and it is expected that the piers will settle out of line and level after the drift jam has begun to form. A system of small ditches will conduct the water away from the barrier across the made flat to the channel, leaving the river to cut the remainder. Figs. 4 to 9 show various features of the barrier, and Figs. 10 and 11 show some of the drift collected by it during the floods of November and December, 1915.

The underlying idea of the whole design is eventually to form across the valley a log jam which will in effect be a dam, thereby spreading the stream over a width of from 1 800 to 2 000 ft., instead of 400 ft. as heretofore, diminishing both the depth and the velocity and causing drift to be deposited, or to become interlaced and held, instead of being carried over the crest, thus further strengthening the dam itself and eliminating a maintenance charge for the removal of drift. If the natural actions of the river are a criterion, the present channel will become filled, the current being forced farther and farther across the valley as successive spans become impassable, and sand and gravel will reinforce and solidify the accumulation of débris in the dead water.

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PAPERS AND DISCUSSIONS

CHEMI-HYDROMETRY AND ITS APPLICATION TO THE PRECISE TESTING OF HYDRO-ELECTRIC GENERATORS

Discussion.*

By W. S. Richmond, M. Am. Soc. C. E.

W. S. Richmond,† M. Am. Soc. C. E. (by letter).—The excellent use which Mr. Groat has made of his exceptional opportunity to carry on experiments in hydraulic measurements, while performing important hydro-electric tests, is highly commendable. It would seem that every item of the work had been considered, experimented upon, and discussed, in so far as it was at all pertinent. The paper is a very valuable addition to hydraulic literature. Mr. Richmond.

Mr. Groat remarks that in some cases, where apparently excellent current-meter work has been done, the results are chargeable to art as much as to science. With this idea the writer agrees, and he believes the fact is not objectionable, as he understands the author's remark to indicate. Long familiarity with the Haskell meter has convinced the writer that its use and care involve as much of art as of science in those instances where it is made to give the best account of itself, exactly as is the case in the delicate manipulation of a transit or a ruling-pen.

The writer had the great pleasure of spending an hour with Mr. Groat at Massena in 1914 while the tests were in progress. He did not see any current-meter measurements being made, but did see the gauging sections, and was permitted to examine the current meters. The writer then felt that the author had before him a difficult task

* Discussion of the paper by Benjamin F. Groat, M. Am. Soc. C. E., continued from February, 1916, *Proceedings*.

† Detroit, Mich.

Mr. Richmond. in both the chemical and the current-meter gaugings. On the one hand, conditions of low head, large volume of flow, and short distance between dosing and sampling sections appeared disadvantageous for the chemical gauging; and, on the other hand, the sections necessarily chosen for the current-meter observations were obviously poor. Moreover, the chemical gauging was pioneer work. So far as the writer's knowledge goes, the only other instance of chemical gauging of importance in connection with the testing of hydro-electric generating units in America is that by Mr. Abraham Streiff for the Fargo Engineering Company, at the Croton power-house, on the Muskegon River, in May, 1914. The agreement of discharge measurements by chemical and by current-meter methods there is reported to have been 1.3 per cent. Great credit is due to Mr. Groat for obtaining such accuracy as he has in the chemical gauging, and he is to be congratulated on the excellent apparent agreement of results by chemical and current-meter methods.

The author states that the rigid method of support is very unfavorable to the Haskell meter, and that it is favorable to the Price meter. This is strikingly shown in the results of the experiments performed in the Naval Tank at Ann Arbor. The large errors introduced in the case of the Haskell meter are surprising, and indicate clearly that this method of support should not be used if it can be avoided. During the work at Massena in 1911 the meters were provided with tails, and were supported by rods or cables in such a manner as to be free to swing both horizontally and vertically. The results then obtained at very poor sections showed comparatively small errors in the Haskell meter, and rather large errors in the Price meter. The conclusions then reached were in general harmony with those of the writer, who has used only meters provided with tails and suspended by cables. In this case the angle which the meter makes with the perpendicular to the section at the same point must be measured with sufficient accuracy, and the proper correction applied where necessary. That none may be misled, it seems proper to point out that no errors will result when a Haskell meter, provided with a tail and suspended by a cable, is used carefully at a really good section. That the head-race section at Massena was very poor is shown with sufficient clearness by those observations in the double vertical, No. 5, where the divergence between Haskell and Price meters (assuming no change in still-water ratings) indicates a transverse component of velocity approximately one-half as great as the axial component.

The writer cannot agree with Mr. Groat that "under the most favorable circumstances" current meters may indicate velocities in error by 2 to 8% or even more, when an ordinary still-water rating is assumed to apply. Haskell and Price meters used by the writer have shown no such errors, except when used under unfavorable cir-

Mr. Richmond.

cumstances, and the error of the Haskell meter has been small under very unfavorable conditions. The writer has used the small Price meter when it over-registered by 34%, and the Haskell meter when it under-registered by 7%, but the conditions had been made exceedingly unfavorable purposely. The maximum error observed by the writer while actually gauging stream flow was approximately 11% for a large Price meter, well rated and in good condition, but suspended from a catamaran which was pitching in a sea so as to give the meter a vertical motion of 3 or 4 ft. amplitude. Under similar circumstances, the error of the Haskell meter has been too small to be determinate. Either meter will frequently give errors of from 1 to 2% in a single short-run measurement, but, under favorable conditions, the mean of several measurements will be the true velocity that obtained, within a fraction of 1 per cent. The writer firmly believes that a B-type Haskell meter, in fine condition, skillfully used, in smoothly flowing, reasonably clear water such as obtains at well-chosen gauging sections on the large streams of the Great Lakes system, may be relied on to indicate the true velocity within a fraction of 1% when its still-water rating is applied, provided the velocity is more than 1½ ft. per sec., and the mean of several runs is taken. A Haskell meter frequently will not remain in such a condition long, without attention, and it is necessary to use another meter, or some other equally accurate device, simultaneously, in order that instant knowledge may be had that something is wrong, so that the trouble may be remedied at once. In most of the work of the U. S. Lake Survey, three or more meters have been used on any piece of gauging, two meters being operated simultaneously at the same elevation a few feet apart. By changing meters frequently, and pairing them in as many combinations as possible, it is usually easy to tell which, if any, have changed their ratings, either temporarily or permanently. This has been called the "two-meter method", and, the writer believes, was devised by F. C. Shenehon, M. Am. Soc. C. E., formerly of the Lake Survey, and now of the University of Minnesota. In all Lake Survey work the Haskell meter has been used with tails on the body of the meter and on the weight, the meter being suspended on a flexible cable. This method the writer heartily recommends.

That the still-water rating is applicable without correction in the case of the Haskell meter when used at a good section has been demonstrated in several different ways by the work of the Lake Survey. Perhaps the best test was that made in 1906 in the Detroit River by Mr. Shenehon, under the general supervision of Mr. Haskell. In these experiments, two very stable, light-draft, catamarans were anchored in the river in tandem, being held at a certain distance apart by wires. A Haskell meter was suspended 12 ft. from the side of each catamaran, and 1 ft. deep, the two meters being in the same cur-

Mr. Richmond

rent thread, one 205 ft. down stream from the other. Liquid bluing was injected into this current thread several feet up stream from the up-stream meter, and carefully timed over the distance between the meters, while the meters simultaneously recorded their revolutions electrically. Seventy-six such observations were made, the mean velocity being 2.862 ft. per sec. by the bluing, and 2.859 by the meters.*

Another proof is furnished by the simultaneous use of Haskell and Price meters in the St. Clair River in 1909. The writer was not then familiar with the experiments by C. H. Miller, M. Am. Soc. C. E., and was considerably chagrined at the time because the meters did not always agree. He soon noticed that the principal discrepancies occurred on those days when the observing catamaran had a vertical motion, due to waves on the river, and that the divergence between the meters increased with the vertical motion. It was found that the measurements by the Haskell meters, when related to the corresponding stage and slope of the river, satisfied very closely the equation expressing the mathematical relation of discharge to stage and slope, and that the discharge measurements by the Price meters were too great. This equation had been derived from the results of a great many measurements, most of which had been made under smooth-water conditions, so that the equation itself contained no appreciable error from this cause. Furthermore, on comparatively calm days, simultaneous measurements by the Haskell and Price meters agreed within about 1 per cent. Mr. Groat has shown that in such case the true velocities lie between the values by the two meters. In 1910 the writer made oscillation experiments at a rating base and at one of the hydraulic sections, the results agreeing closely with those obtained by Mr. Groat at Massena in 1911, and showing that a much larger correction must be applied to the Price than to the Haskell meter indications. The Haskell meters, therefore, probably were correct within less than 0.5 per cent.

A third proof was obtained in 1914 at a gauging section on the St. Lawrence River, using a Pitot tube simultaneously with a Haskell meter. The Pitot tube was in general patterned after that recommended by W. M. White,† M. Am. Soc. C. E., and also used by Mr. Groat at Massena in 1911. This tube has been shown by both these gentlemen to give very accurate velocity indications in a current. The writer also made careful experiments confirming their opinions concerning the accuracy of the static orifice. Several sets of simultaneous observations with Haskell meters and the tube were then obtained in a very smoothly flowing current of about 4.2 ft. per sec. The mean result showed the meters in agreement with the tube within 0.4 per cent.

* This test is described more at length in Senate Doc. 105, 62d Cong., 1st Sess., pp. 72–74.

† *Journal* of the Association of Engineering Societies, Vol. 27, August, 1901.

Mr. Richmond.

As an indication of the precision that may be obtained in current-meter gauging of large rivers, it may be stated that three separate sections on the St. Clair River, many miles apart, and of entirely different characteristics, showed mean agreements of discharge within 0.4% when compared through the relations of discharge to stage and slope. Similarly, three sections on the Niagara River showed an outside agreement of 1.3%, and two sections on the St. Lawrence River agreed within 0.4 per cent.

AMERICAN SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

A REVIEW OF THE REPORT OF CAPTAIN ANDREW TALCOTT CHIEF ENGINEER MEXICO AND PACIFIC RAILROAD EASTERN DIVISION FROM VERA CRUZ TO MEXICO EXPLORATIONS SURVEYS ESTIMATES 1858

Discussion.*

By Messrs. L. Perez Castro and T. M. R. Talcott.

L. Perez Castro,† M. Am. Soc. C. E. (by letter).—This paper is very useful to those interested in the history of the leading railways of Mexico. The history of the grants and concessions, as well as of the progress of construction of the Mexican Railway, can be learned from the official reports of the Mexican Government, but very little has been published in reference to the engineering achievements of the pioneers on this wonderful railway. In fact, from the reminiscences of the living men of that epoch, it is rather difficult to get extensive information about the matter. Mr. Castro.

At present, the reports of Capt. Talcott and his assistants have essentially an historical value, as the ideas now prevailing in reference to the location and construction of railways in Mexico are different from those of a quarter of a century or more ago, on account of the dissimilar conditions now obtaining. There are some engineers in Mexico, familiar with the country crossed by the Mexican Railway, who believe that its location could have been improved by following another line, but adhering to the same route south of the "Pico de Orizaba".

At the present time the volume of traffic carried by the railways of Mexico is far greater than that of former years, but, on the other

* Discussion of the paper by Emile Low, M. Am. Soc. C. E., continued from March, 1916, *Proceedings*.

† City of Mexico, Mexico.

Mr. Castro. hand, the cost of fuel has increased considerably. A large proportion of the coal has to be imported. Recently, the use of Mexican fuel oil has resulted in great economy in the transportation expenses of these railways, but not enough to determine a change in the criterion relating to the maximum grades, for the price of fuel oil is steadily increasing.

The construction of the Interoceanic Railway, *via* Jalapa, is more in harmony with the actual requirements as to ruling grades, in the descent from the "Mesa Central" (Central Plateau) to the sea-level lands, as its heaviest grades are from 2.5 to 3%, instead of the 4.5% of the Mexican Railway (in both cases without compensation for curvature). The maximum curvature in each is about 12° (20-m. chord), or between 90 and 100 m. of radius. Wherefore, the Interoceanic Railway, in spite of the handicap of its present narrow gauge (0.914 m., or 3 ft.), has secured a greater freight traffic than the Mexican Railway, of standard gauge. It can be estimated that, before the outbreak of the political disturbances in Mexico, 60% of the freight from Vera Cruz to the table-lands was handled by the Interoceanic and the remainder by the Mexican Railway. The passenger movement has always been considerably superior on the latter railway, owing to the greater speed and comfort in making the trip, and also on account of its more attractive scenery.

With the facilities now available in the line of construction, and considering the necessities of an intensive traffic, it is admitted that the maximum grade suitable in the mountainous parts of Mexico, *viz.*, in climbing to the high lands, is 2% compensated for curvature, with maximum curves of 6° and, exceptionally, 8° (191 and 143 m. of radius, respectively, 20-m. chord). With this grade and 6° of sharp curves, a new line has been located between Las Vigas and Vera Cruz, on the Interoceanic Railway, and this will surely be constructed when the contemplated widening of the present narrow gauge takes place. The projected short line between Mexico City and Tampico—which is a pressing necessity—undoubtedly will be realized with such maxima of grade and curvature, notwithstanding the tremendous difficulties to be overcome in descending from the "Mesa Central", whichever route may be selected as suitable for the purpose. The different and numerous surveys have demonstrated that with 2.5% grades, the work would be somewhat simplified, although the prevailing tendency favors the maximum of 2 per cent.

With modern developments in electrification matters, and the use of hydro-electric power—which can be improved to a great extent in the Mexican mountains—the present limitation of grades can be economically increased; but, in the construction of new lines, the tendency at present is to exceed such limitations and use such lines exclusively for passenger and express purposes, like the Mexico-Puebla line, passing between the snow-capped volcanoes, Popocatepetl and Ixtacíhuatl, and the Mexico-Toluca line, through the "Sierra de las Cruces", the construction of which was being carried out by the Mexico Tramway Company when it was delayed by the political troubles of the country. The maximum grade adopted on these lines is 6%, but on heavy-traffic lines already in existence, such as the Mexican Railway, surely in the near future, hydro-electric energy will be used, resulting in greater economy than that obtained with fuel oil as a substitute for coal. Mr. Castro.

On the lines in the "Mesa Central", the southerly part of which is essentially hilly, it is now estimated that 1% is the maximum economic grade, compensated, with 6° of greatest curvature, instead of the 1.5% grade largely used hitherto. The section of the Mexican Railway between Mexico City and Boca del Monte reaches in some stretches 1.5%, but surveys have been made with the object of reducing it to 1%, and it is possible that, when the conditions of the country are improved, this work will be started. On the Interoceanic Railway, between Mexico City and Las Vigas, similar surveys have been made for the purpose of making the necessary betterments in location when the road is widened to standard gauge. In the low country, lying between the foot of the mountains and the sea, the reasonable maximum grade is 0.5%, compensated, with maximum curvature of 2% (573-m. radius, 20-m. chord) and eventually 4° (287 m.). Thus has been located the coast line, pending construction, by the National Railways of Mexico, between Vera Cruz, Tampico, and Matamoras, the latter point on the United States border. In the surveys of the line from the Isthmus of Tehuantepec to the Yucatan Peninsula, grades of 1% have been proposed—and higher still in the neighborhood of Campeche—but this should not be approved as it would indicate a bad selection of the route, the land making it easy to keep the limit at 0.5 per cent.

T. M. R. Talcott,* Esq. (by letter).—When Capt. Talcott assumed the duties of Chief Engineer of the Mexico and Pacific Railroad, in December, 1857, he was in his sixty-first year, and it was deemed desirable that one of his elder sons should accompany him as his personal assistant. For this the writer was to some extent qualified as he had had 18 months of previous training in that capacity on the Ohio and Mississippi Railroad, and had assisted his father in astronomical observations for the State of Virginia. Mr. Talcott.

Some preliminary examinations of the ascent from Vera Cruz to the *cumbres* had been made by Mr. P. Almazan, a Mexican engineer, prior to the arrival of the expedition at Vera Cruz on January 4th, 1858. As Capt. Talcott was anxious to verify the barometrical eleva-

* Richmond, Va.

Mr. Talcott. tions of some of the passes ascertained by Mr. Almazan, without waiting for the delayed transportation, he and the writer left Vera Cruz by diligence on the night of January 10th, and arrived at Orizaba the next afternoon.

Having obtained saddle horses and a competent guide, the party started early on January 12th on the first of the many explorations on horseback in advance of the engineer parties, spending 5 days in the saddle, during which an examination was made of the route of the Diligence Road *via* Aculcingo as far west as Puente Colorado, a summit south of Aculcingo, which Mr. Almazan reported lower than the Aculcingo Pass, but which was found to be higher; the Canada de Regina Pass was also examined, and a route between Orizaba and Cordova which crossed the Barranca de Metlac north of the Diligence Road. The return to Vera Cruz was made by diligence on January 17th, and soon thereafter the engineer parties were fully equipped and in the field.

After a week spent at "Camp Escandon", near Vera Cruz, Capt. Talcott's next start was on horseback with the writer, and a Mexican *mozo* to care for the horses. The writer finds, from the only notebook which he has preserved from that period, that from January 25th to 31st, while on the way to Orizaba, he recorded astronomical and barometrical observations at Soledad, Chiquihuite Summit, and Potrero.

Early in February, Capt. Talcott established his headquarters at Orizaba, where he opened an office to which Mr. Coolidge and his assistants were moved from Camp Escandon; and thereafter hourly readings of the barometer and thermometer were recorded there, for comparison with contemporaneous observations by the surveying parties in order to determine elevations at controlling points along the Orizaba route then being surveyed. Astronomical observations were also made regularly for the rating of the several chronometers.

Capt. Talcott made a number of explorations both east and west of Orizaba during February, and the writer's notebook contains records of repeated observations at Maltrata, and at Aquila and Aculcingo Passes during that month.

Later, when there was fighting at Orizaba, Mr. Coolidge joined the "Liberal" party and was made prisoner by the "Conservadores", which for a time complicated the relations of the engineers with the military authorities of that party. Before that, when challenged by sentinels, the engineers were allowed to pass by saying that they were "American Engineers", but afterward they had to explain to officers at military posts that they were "Railroad Engineers" before being allowed to pass.

When there was no longer doubt of the practicability of the Maltrata route, Capt. Talcott extended his personal explorations west of the *cumbres* into the open country of the plains. On these reconnaissances each successive course by compass was recorded, and its length was estimated by the time consumed in traversing it at a steady pace on horseback. In the middle of the day a halt was made in order to get the time by equal altitudes, and the approximate latitude of the halting place by circummeridian altitudes of the sun. Mr. Talcott.

At night, both latitude and longitude were again determined by observations of the stars, thus fixing approximately the geodetic position of two points on each day's journey, from which the latitude and departure of each half day's journey was calculated and used in correcting the approximate scale of estimated distances. From these data the field parties were furnished with rough maps showing the routes traveled and such topographical features as had been sketched *en route*.

On May 25th, Capt. Talcott left Orizaba on horseback, accompanied by the writer and a Mexican *mozo*, and soon thereafter established his headquarters at Puebla. While there, on June 19th, the party had its first experience with an earthquake, but the shock was more severe in the City of Mexico.

On July 12th, according to the diary, the party left by private conveyance for Tlascala "to explore the route from Esperanza to Huamantla and Apam." While on this trip, the writer was left at Nopalucan, Capt. Talcott says, "to take charge of the line commenced by Lyon at Esperanza *via* Nopalucan, etc." This was the line which was finally adopted and built from the Boca del Monte to Apizaco. While the writer was engaged on this line, Capt. Talcott returned to Puebla, and, on July 20th, went thence *via* San Martin to Apam, from which point he made explorations "as far west as Saupauca, in sight of Lake Texcoco and Otumba."

Starting again from Puebla on July 28th, he says he found the writer's party at Huamantla, and went thence, *via* San Andres to Orizaba, and thence returned to Puebla by August 4th. There the writer rejoined him and went with him to the City of Mexico on the 7th, and found that Don Manuel Escandon was in prison because he had refused to pay a forced loan of $400 000 demanded by the *de facto* government of Mexico. No one was allowed to visit him in prison, and after remaining in the city for a week, Capt. Talcott and the writer returned to Puebla without seeing him.

When the surveys were nearing completion, and the question of a general map was being considered, it occurred to the writer that it would be more complete and satisfactory if the Diligence Road from Puebla to the City of Mexico could be shown on it.

Time was short, and all the regular parties were otherwise engaged, so the writer offered to undertake the work and complete it in one week with such assistance as could be spared, including only Mexicans as rodmen and chainmen.

Mr. Talcott. Half a day was lost in starting, by reason of an oversight in not getting a written permit from the Alcalde of the city, which led to the arrest of all in the party except the writer.

The first 20 miles to San Martin were not deemed essential, as this part was covered by information previously obtained, and as time was short the party hastened to that place, where the actual survey was commenced the next morning, starting with the elevation which had been ascertained by repeated observations of the barometer on previous trips by diligence to and from the City of Mexico.

From San Martin to Ayotla the distance was measured by chain, courses were taken by compass, elevations determined by level and rod, and as many as possible of the topographical features of the country between the Diligence Road and the line *via* Apam were fixed by triangulation.

On the morning of the sixth day, after passing over an elevation of about 10 200 ft. at Rio Frio, the party was on the shore of Lake Texcoco, the level of which above the sea had already been determined by the survey *via* Apam, and was surprised to find that the elevation of the lake differed only a few feet from that determined by the survey from Vera Cruz.

The dome of the Cathedral in Mexico being in plain view, its distance was determined by triangulation, and also the course of the causeway across Lake Texcoco, which, for the want of more time, was the best that could be done to connect the line with the survey *via* Apam.

After returning to the United States, in October, 1858, the writer remained with Capt. Talcott for several months, rendered him some assistance in the preparation of his report, and accompanied him to Arizona in 1860, during the interval in which he was waiting for his recall to Mexico.

In 1861, when Don Antonio Escandon sent a special messenger through the Federal lines with letters to Capt. Talcott asking his immediate return to Mexico, neither he nor the writer felt that they could leave the service of the State of Virginia in which they were then engaged on river, coast and harbor defenses; and, later, when Capt. Talcott did return to Mexico, the writer was in the Confederate Army, where he remained until April 9th, 1865, when Gen. R. E. Lee, on whose staff he had been serving, surrendered to Gen. U. S. Grant.

In the spring of 1866, when Capt. Talcott was in great need of engineers to replace those who had left, or were about to leave him, for service with the English contractors, the writer returned to Mexico, taking several assistants of his own selection, and succeeded Gen. W. H. Stevens, who had been in charge of construction on the Maltrata Incline as Division Engineer.

During the months which followed, until the following February, when the French army was withdrawn, the chief occupation was measuring up, and preparing estimates for work done, which were the basis of a subsequent settlement with the English contractors. Mr. Talcott.

In conclusion, the writer cannot refrain from saying that, of all the engineers who served with Capt. Talcott on the survey in 1858, and the work of construction between Vera Cruz and Paso del Macho in 1862 and 1863, Mr. M. E. Lyon, who met his death at the hands of Mexican bandits while in the discharge of his duty, was most conspicuously identified with the enterprise.

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PAPERS AND DISCUSSIONS

COHESION IN EARTH: THE NEED FOR COMPREHENSIVE EXPERIMENTATION TO DETERMINE THE COEFFICIENTS OF COHESION

Discussion.*

By F. W. Green, Assoc. M. Am. Soc. C. E.

F. W. Green,† Assoc. M. Am. Soc. C. E. (by letter).—A rational and satisfactory theory of earth pressure has never been developed. For many years, the designer has had to content himself with an adherence to the theories of Rankine, Coulomb, Weyrauch, and others, based on various assumptions necessary to simplify the mathematical treatment, or to place his reliance on the empirical rules proposed by Sir Benjamin Baker, Trautwine, and others; and then to modify the conclusions thus obtained, in any case, by making certain arbitrary concessions to his experience and judgment. A conscientious engineer deplores such a necessity, which requires him to take chances between stability on the one hand and economy on the other. The author's effort to illuminate this subject in his paper is most interesting and praiseworthy. Mr. Green.

In the Century Dictionary cohesion is defined as follows:

"* * * the state in which, or the force by which, the molecules of the same material are bound together, so as to form a continuous, homogeneous mass. This force acts sensibly at insensible distances—that is, when the particles of matter which it unites are placed in apparent contact. At insensible distances it is a much greater, at sensible distances a much smaller force than gravitation, so that it does not

* Discussion on the paper by William Cain, M. Am. Soc. C. E., continued from February, 1916, *Proceedings*.

† Stamps, Ark.

Mr. Green. follow the law of variation of the latter. It unites the particles of a homogeneous body, and is thus distinguished from *adhesion,* which takes place between the molecules of different masses or substances, as between fluids and solids, and from *chemical attraction,* which unites the atoms of a molecule together. The power of cohesion in a body is estimated by the force necessary to pull its parts asunder. In general, cohesion is most powerful among the particles of solid bodies, weaker among those of liquids, and least of all, or entirely wanting, in elastic fluids, as air and gases. Hardness, softness, tenacity, elasticity, malleability, ductility, and in crystallized bodies, cleavage, are to be considered properties dependent upon cohesion. The most powerful influence which tends to diminish cohesion is heat, as shown in the change of a solid to a liquid, or of a liquid to a gas, which is effected by it."

In all cases in actual practice, it may be said with confidence that the material to be held by a retaining wall is not homogeneous in the scientific sense. It may be all earth, but it is very doubtful, indeed, if it will ever be strictly homogeneous earth; and, if not homogeneous, it cannot be acted on by the force of cohesion. In the writer's opinion, therefore, the apparatus shown in Fig. 1 cannot measure cohesion. The ratio of Q to P_n is the coefficient of static friction of the material tested.

It is well known that the coefficient of friction is highly variable. In the Galton-Westinghouse tests, it was found that its value varied from 0.074 at 60 miles per hour to about 0.340 static, using cast-iron brake-shoes on steel tires. Static friction itself is far from being a constant quantity, moisture and temperature greatly affecting it. Rankine* gives for clay, from damp to wet, values for f varying between 1.00 for the former to 0.25 for the latter. In the writer's own experience, he has encountered an alluvial silt which, after thorough saturation, took a slope of 7 : 1, or a value for f of 0.143. May we not with propriety conclude, therefore, that the failure of so many retaining walls is chargeable to the use, by the designer, of a coefficient of friction which, in theory, is based on a dry granular material, but, in fact, on a wet, slippery material, rather than to a failure to introduce a cohesion factor into his computations? In other words, if proper consideration is given to the phenomenon of a variable adhesion, will the problem not resolve itself into the same thing as a constant coefficient of friction (which is the measure of the constant adhesion) plus a so-called cohesion factor (which, in reality, indicates the upper and lower limits between which variable adhesion fluctuates)? If the wall is designed for the worst anticipated conditions, as to nature of back-filling, drainage, frost, etc., instead of for "a dry granular mass without cohesion, etc.", it should not fail if properly constructed.

* "Civil Engineering", p. 316.

Cohesion is stated by many writers as being the force which prevents the sides of newly excavated trenches from caving in, and the material taking the natural slope. In the writer's opinion, which is admittedly iconoclastic, this is nothing more than another illustration of the variable nature of adhesion. The material before excavation is thoroughly compacted, that is, the particles are in especially intimate contact, so intimate, in fact, that the force of gravitation cannot at once unbalance the interior forces and thus produce movement. Eventually, moisture evaporates, atmospheric pressure enters, and then gravitation wins. Mr. Green.

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PAPERS AND DISCUSSIONS

SECURE SUBWAY SUPPORTS

Discussion.*

By Lazarus White, Assoc. M. Am. Soc. C. E.

Lazarus White,† Assoc. M. Am. Soc. C. E.—This paper opens up several topics for discussion. Of course, the important thing is always safety—"safety first". The fundamental feature of this paper is that it advocates the design, by the contractor, of a system which will guarantee absolute safety to the public; and, at the same time, other conditions are given. The system, it is stated, must also be economical as regards cost of erection. Is it possible in a system of temporary supports to have absolute safety and economy at the same time? Mr. White.

The usual subway contractor cannot allow much more than $1 per yd. for supports. If he did he would never get a contract, and if he tried to obtain absolute safety, the cost would be prohibitive, as that is something which cannot be realized.

In the speaker's opinion, all that can be done is to adopt a design which has a reasonably safe margin, and then trust to rigid supervision on the part of the engineers and contractors to keep it safe.

No system of support, however designed, can be safe in itself. It is placed, day and night, by various gangs of timbermen, who have to be trusted to a great extent. They have to work under a series of difficult conditions, at various heights, and on underground structures, all of which require modifications in the supports. No predetermined design could be made to fit these conditions, and, if the contractors tried to make a rigid design, they would get into trouble.

The next point is the supposition that, if the timbering were designed in advance by the engineers who prepare the contract, that is, the engineers of the public service commission, greater safety—

* Discussion of the paper by A. B. Lueder, M. Am. Soc. C. E., and W. J. R. Wilson, Esq., continued from March, 1916, *Proceedings*.

† New York City.

Mr. White. the speaker will not say "absolute safety"—could be secured, and the contractors would be bidding on the same basis; but, the speaker agrees with most of those who have discussed this matter, that this would not be desirable.

These contracts are prepared in great haste, and the commission engineers have not the time to design these timbering systems to meet the varying conditions of the different contracts; and if they were designed, the speaker does not believe that the contractor could follow them absolutely, at least, he would ask for changes, and then he would have the responsibility.

As a matter of fact—the speaker does not know whether it is intended—it seems to be an inference that the timber systems used in other structures have been erected by carpenters and various foremen. The speaker knows that such is not the case. For the last 10 or 15 years most of the contractors have had engineers, and very competent ones—members of this Society—who have designed their timber systems and looked after them. Thus, most of the timber systems were designed by competent engineers; and it makes very little difference whether they were or were not in the employ of the State.

The paper lays great emphasis on the benefit of getting out rock in large sizes, as this is considered to be safer and more economical. On that point there is a fair difference of opinion. The firm with which the speaker is connected put in bids on most of the main subway contracts, and examined the various methods of rock excavation, visiting most of the places where work was under way. The impression gained was that in those cases where it had been planned to break up the rock into small pieces (about two-man size) the material was being handled more expeditiously, and more economically than those which handled the rock in large sizes. Although the speaker's firm is at work on only one subway contract which has no rock excavation, its members have been in charge of rock excavation and open-cut aqueduct and tunnel excavation, and therefore may fairly claim to be familiar with rock excavation methods.

To handle large rocks requires very large appliances, and there is always a risk of break-downs. There is no difficulty in breaking up large rocks in the cut. With rotating drills they are very easily drilled, and then can be shot, either with the main shots or at other times.

The paper states that the rock shown on a truck, in Fig. 15, weighs 25 tons, but a calculation seems to indicate that it could not have weighed more than 10 tons.

The speaker believes that the most valuable part of the paper is that which deals with longitudinal supports. In that he agrees with the authors. Such supports are of enormous value in subway construction, in safeguarding it to a very large extent, and they introduce a great element of flexibility; but they are not by any means new, or peculiar to this one job, for they have been used for the last 10 years or longer, and, in fact, patents have been granted for supports of this type. Mr. White.

In the speaker's work he has also used longitudinal supports in the timber system, but they are quite different from those described in the paper. Longitudinal supports are all right, but it cannot be said that entire reliance can be placed on them, because the intersection of the cut is left unprotected. There is a street crossing about every 200 ft., and this requires as much support as the main street, because there are found pipes, conduits, etc.; so that, for these places at least, transverse supports are necessary.

Rock slides are a great element of danger, but there is something peculiar about a rock slide, it sometimes requires very little support to prevent it. A slight transverse support might prevent it from sliding. There is an enormous difference between nothing and some support.

A point is made of the fact of the permanency of steel compared with timber. It is hard to conceive of a timber system that would not last the length of a subway job without deteriorating; otherwise it would be unfit for use in the first instance.

The authors express the hope that blasting may be eliminated, as being a source of danger. It is a source of danger, of course, but there is about as much chance of eliminating blasting from subway rock work as of eliminating powder from war.

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PAPERS AND DISCUSSIONS

A STUDY OF THE BEHAVIOR OF RAPID SAND FILTERS SUBJECTED TO THE HIGH-VELOCITY METHOD OF WASHING

Discussion.*

By Messrs. George E. Willcomb, H. Malcolm Pirnie, John H. Gregory, F. A. Barbour, and George A. Johnson.

George E. Willcomb,† Assoc. M. Am. Soc. C. E. (by letter).—This paper, presenting a scientific discussion of the many factors relating to the high-velocity wash of a rapid sand filter, is timely and instructive. The literature on the washing of rapid filters is meager. Most of the published reports are based on the individual conclusions of different operators arrived at without any extended research, and, from necessity, they contain frequent instances of inaccuracy of interpretation. This paper is especially timely in that it tends to focus attention on the general subject of filter washing at a time when radical action on the question seems imminent. At a recent meeting of a western engineering society, the air-wash as applied to rapid filters was adversely criticized, and a member of the engineering staff of a State Board of Health took the extreme position of recommending that it be abolished in future plants. Such views as these emphasize the importance of research work in connection with filter washing, in order that such a useful adjunct to the washing process as air agitation may not be rejected without good reason. Eastern plants, operating with a water of low turbidity and high in color and sewage contamination, have found the air-wash to be most efficient, and plants constructed 12 years ago are having continued success with this means of agitation. It has been found that most of the troubles have been Mr. Willcomb.

* Discussion on the paper by Joseph W. Ellms, M. Am. Soc. C. E., and John S. Gettrust, Esq., continued from March, 1916, *Proceedings*.

† Albany, N. Y.

Mr. Willcomb. physical, that is, have been caused by faulty design of the air-wash system.

On the publication of the report of the Commissioners of Water-Works of Cincinnati, in 1909, in which the placing of screens at the junction of the sand and gravel was advocated, many filtration engineers of extended experience in the operation of rapid filters were skeptical as to the benefits to be obtained by the use of such screens at this point. To be sure, the condition brought about by the placing of such screens was almost ideal, for certainly no mixing of the sand with the gravel could result; yet, owing to the stresses that were likely to act on the screen at the beginning and end of a wash, and the likelihood of uneven distribution of the wash-water, all factors seemed to be against any permanency of alignment of the screen.

The ridge-block construction for filter bottoms, though old in principle, has been rapidly developed during the past 5 years, and varying modifications of this type have been incorporated in the design of several plants of recent construction. The advantages of this system are: a smaller volume of gravel is required; unwashed zones in the gravel medium are eliminated; and jet action of the incoming wash-water is prevented. The disadvantages are: increased cost and complication of the construction; the inherent weakness of the design tending toward shearing the anchor-bolts and thus letting sand into the collector channels; and the trouble involved in overhauling the beds during periods of rejuvenation.

As long as a screen for holding down the gravel was used, and only the trapezoidal channels were filled with gravel, there is no doubt that this system assured an even distribution of the wash-water and prevented unwashed zones; but, as soon as the retaining screen was done away with and the gravel layer increased above the tops of the channels, dead spaces were introduced and practically all the advantages of the system were lost.

From the extended experimentation, the grading of the gravel appears to be of the utmost importance. This paper proves conclusively that the depth and the arrangement of the sizes do not cause a loss of head of more than 0.3 ft. even with a 2-ft. vertical rise. The function of the gravel layer being to support the sand medium, distribute the wash-water, and prevent sand grains from entering the under-drain system, the writer has come to the conclusion that 14 in. of graded gravel, a simple type of sand-valve, and a flat floor, represent optimum conditions, both in regard to economy and good design. That portion of the gravel surrounding the sand-valves should be composed of large units, say from 2 to 3 in. in diameter, and should be at least 4 in. thick. The next layer ranges from 1 to $1\frac{1}{2}$ in., and is 2 in. deep. Next should come a 3-in. layer, ranging from $\frac{3}{4}$ to $\frac{1}{2}$ in. The next layer is $2\frac{1}{2}$ in. thick, and runs from $\frac{1}{2}$ to $\frac{1}{4}$ in., followed by a $2\frac{1}{2}$-in.

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layer of $\frac{1}{4}$ to $\frac{1}{16}$-in. size. Gravel graded in this manner provides for adequate deflection of the wash-water jet without undue throttling, and allows of a much wider spacing of the sand-valves than is customary. The tendency of the wash-water is to follow up the surfaces of the large gravel units, and conditions are brought about that are quite akin to the mathematical placing of spherical bodies around the valves, a procedure that has been introduced with favorable results quite recently. The main factor to be considered in placing the gravel is the proper sizing of the various layers. Generally speaking, a layer of gravel will remain on top of a lower layer, provided it contains no particles less than one-third the size of the particles on which it rests. The gravel adjoining the sand should not be too coarse in relation to the sand, else mud-balls will tend to be deposited by a too sudden decrease of the velocity during the filtration period proper.

When the Albany experiments in double and rapid filtration were begun in 1905, data were available from the experimental plants at Philadelphia, Cincinnati, and Columbus. At this time the ridge-block under-drain system and high rates of washing were being exploited, and accordingly a small filter with an inverted cone depression at the under-drain was experimented with. A very simple cylindrical sand-valve was developed from seamless brass tubing of No. 20 stock, Stubb's steel wire gauge. The tubes were punched out of one piece with a die, and cost 9 cents apiece to manufacture. The tubes were 4 in. long and had a $\frac{5}{8}$-in. bore. There were two rows of staggered holes, $\frac{1}{4}$ in. down from the top, each being 0.161 in. in diameter. Each hole had an area of 0.02036 sq. in., and the combined area of the eight openings amounted to 0.1629 sq. in., which was 0.2% of the entire filter surface. This was a smaller rate than usual, and gave rise to a friction loss of head of 3.0 ft. when washing with a vertical rise of 1 ft. The bottom of the tube was made with a flare, and two sets of depressions were sunk into the vertical sides to form a bond when they were concreted into the filter bottom. When the valve was in place in the bed, the holes of the lower set were only $\frac{1}{4}$ in. above the filter floor, thus preventing the silting up of any portion of the gravel under-drains.

This small filter had a glass side through which the effects of the washing could be observed. The gravel layer consisted of 12 in. of selected pebbles, graduated from 3 in. to $\frac{1}{8}$ in., and on this was placed 24 in. of a 0.32-mm. sand having a uniformity coefficient of 2.50. Different rates of washing were used up to 2 ft. rise, and no tendency of the sand to mix with the gravel was noted. On starting the wash, the entire sand body would rise for a distance of from 4 to 6 in., when the bottom particles would begin to detach themselves and take up the motion of the various currents. Great importance was attached to this phenomenon at the time, for it was thought that the violent breaking away of the sand particles would shear the strands of organic

Mr. Willcomb. matter attached to the sand grains when the large filters were placed in operation, and thus aid materially in the washing process. It soon became apparent, however, that these conditions were not typical, owing to the restricted sand surface of the experimental filter, and that surface tension had a lot to do with the phenomenon, which would not occur in the large beds. The results of these experiments indicated that washes up to 2 ft. rise per min. could be safely used without admixture of the sand and gravel.

When the sixteen large units were built, flat floor bottoms were decided on, as the advantages of the bottom with pyramidal pockets did not justify their additional cost of construction. The results obtained with the experimental filters had clearly demonstrated that the rapid filters, operating as scrubbers without coagulation, would not wash the sand in place in the bed indefinitely, but would have to be given supplemental washes periodically by ejection or other means. As ejection meant removing all the sand down to the gravel, and as this process would be likely to disturb the gravel layer, it was deemed probable that the gravel might have to be regraded at intervals, and that the pryamidal depressions in the floor, in such a case, might interfere with the work.

The sand-valves developed in the experiments were used in the construction of the large beds. These valves were cast in small slabs outside the beds, and, when hardened, were set over trapezoidal ducts formed in the floors of the filters. These ducts ran across the beds and discharged into a main collector of 2 ft. diameter. The main collector and the under-drain ducts acted as a compensator for the wash-water, and insured equal distribution throughout the bed during the wash. The valves were set 9 in. on centers, and were covered with 1 ft. of gravel graded in four lots from 3 in. to $\frac{1}{16}$ in. A depth of 30 in. of silica sand, of 0.45 mm. effective size and a uniformity coefficient of 2.50, was eventually selected for the filter medium. The beds were divided into two parts by the central wash-water gullet which ran the long way of the beds. The wash-water troughs were of rectangular section, 6 in. deep and 10 in. wide (inside dimensions), and were 7.5 ft. apart. One-half of their top opening was closed on the discharge end, so that the maximum travel of any particle of suspended matter was about 4 ft. The crests of the wash-water troughs were placed 10 in. above the normal surface of the sand, and, during the wash, with a 1.5-ft. rise per min., the sand was elevated 6 in.

As long as the sand was new, no difficulty was experienced in washing the beds. At the rate of a 1.5-ft. rise, the entire sand medium was in suspension and agitation, and, after the expenditure of about 3% of the entire yield for wash-water, the beds were washed satisfactorily.

Table 3 shows the condition of the new sand in place in the bed after a month's run. Four stations were selected in the filter, and

TABLE 3.

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Section.	Before Washing. Effective size.	Uniformity coefficient.	Percentage of moisture.	Turbidity.	Organic nitrogen.	Oxygen consumed.
A—Top (0 to 10 in.)....	0.35	2.08	5.9	360	0.04	7.3
B— " " "	0.33	2.24	6.4	480	0.12	6.0
C— " " "	0.38	1.95	5.6	240	0.00	7.9
D— " " "	0.37	1.67	6.4	370	0.00	8.3
Average...........	0.36	1.98	6.1	360	0.04	7.4
A— (10 to 20 in.)....	0.36	2.37	5.2	105	0.00	5.5
B— " "	0.42	2.38	5.1	110	0.00	4.8
C— " "	0.38	2.23	5.3	75	0.00	6.2
D— " "	0.50	2.80	4.5	115	0.04	9.5
Average...........	0.40	2.44	5.0	100	0.01	6.5
A— (20 to 30 in.)....	0.54	2.77	5.5	130	0.00	4.4
B— " "	0.49	3.26	7.4	60	0.00	3.8
C— " "	0.40	3.00	5.7	120	0.00	5.6
D— " "	0.52	3.07	4.5	105	0.00	8.4
Average...........	0.49	3.02	5.8	104	0.00	5.6

AFTER WASHING.

Section.	Turbidity.	Organic nitrogen.	Oxygen consumed.
Avge. *A* + *B* (0 to 10 in.)....	165	0.00	6.6
" *C* + *D* (0 to 10 in.)....	110	0.04	5.1
" *A* + *B* (10 to 20 in.)...	115	0.00	6.9
" *C* + *D* (10 to 20 in.)...	50	0.00	4.4
" *A* + *B* (20 to 30 in.)...	90	0.00	5.9
" *C* + *D* (20 to 30 in.)...	60	0.00	4.3

EFFICIENCY OF WASHING.
Percentage of Reduction.

Section.	Turbidity.	Organic nitrogen.	Oxygen consumed.
0 to 10 in....................	62.1	50.0	20.7
10 to 20 in....................	18.5	....	13.1
20 to 30 in....................	27.7	....	8.1

tests were made on 10-in. sections from top to bottom. For the chemical work, 100 grammes of the sand were shaken in the sand-engine with 100 c.c. of distilled water for 1 min.; then the whole was diluted to 1 liter, and the different determinations were made on the stock suspension. The newness of the sand is shown by the low percentage of moisture retained on the grains. No organic coats had been formed on the sand at this point, as is also shown clearly by the organic nitrogen and oxygen consumed factors. It is interesting to note the grading of the sand according to the hydraulic values of the grains. As the depth of sampling increases, the effective size increases in like proportion. This grading of the sand is much more marked in the case of a fresh sand than with an old one. There is less friction to the passage of the grains in the former case, and stratification is brought about at the conclusion of the wash. It will be noticed, however, that the uniformity coefficients of the bottom samples are high, denoting the presence of much fine material at the bottom of the bed. It has been found by experience that to accomplish complete stratification according to the hydraulic values of the grain is practically impossible. Convection currents and the liberation of entrained air during the washing process have more or less effect in defeating the

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attainment of this condition, especially in the case of old sand coated with organic growths.

TABLE 4.

Section.	Before Washing.					
	Effective size.	Uniformity coefficient.	Percentage of moisture.	Turbidity.	Organic nitrogen.	Oxygen consumed.
A—Top (0 to 10 in.)...	0.52	1.52	16.6	1 750	1.60	16.5
B— " " " ...	0.61	1.64	17.7	1 750	2.20	19.7
C— " " " ...	0.58	1.72	15.9	1 800	2.00	18.7
D— " " " ...	0.58	1.76	13.1	1 600	1.60	15.3
Average...........	0.57	1.66	15.7	1 725	1.90	17.6
A— (10 to 20 in.)...	0.61	1.70	10.1	1 750	1.44	15.7
B— " " ...	0.60	1.80	9.7	1 400	0.96	15.5
C— " " ...	0.56	1.98	12.8	1 500	1.04	14.1
D— " " ...	0.55	1.83	9.3	1 200	0.88	9.0
Average...........	0.58	1.83	10.5	1 460	1.08	13.6
A— (20 to 30 in.)...	0.60	2.00	8.3	1 200	0.64	12.3
B— " " ...	0.65	1.67	8.3	1 250	0.24	12.5
C— " " ...	5.55	1.83	10.8	1 400	0.72	11.7
D— " " ...	0.57	1 77	13.5	1 400	0.80	9.5
Average...........	0.59	1.82	10.2	1 320	0.60	11.5

After Washing.			
Section.	Turbidity.	Organic nitrogen.	Oxygen consumed.
Avge. *A* + *B* (0 to 10 in.).	1 600	1.80	17.3
" *C* + *D* (0 to 10 in.).	1 500	1.60	15.1
" *A* + *B* (10 to 20 in.)	1 400	0.96	14.5
" *C* + *D* (10 to 20 in.)	1 400	0.96	8.4
" *A* + *B* (20 to 30 in.)	1 350	0.24	13.7
" *C* + *D* (20 to 30 in.)	1 250	0.64	9.9

Efficiency of Washing. Percentage of Reduction.			
Section.	Turbidity.	Organic nitrogen.	Oxygen consumed.
0 to 10 in..................	10.2	10.5	7.4
10 to 20 in..................	3.6	11.1	16.2
20 to 30 in..................	.....	25.1	15.7

Table 4 shows the condition of the same filter after it had undergone a summer's ripening. The effective size of the sand had been increased by successive scrapings of fine sand from the surface. In considering these data it must be borne in mind that the filter was operating as a scrubber, filtering water which had received 12 hours of plain subsidence. It will be noted that stratification is no longer as pronounced. The organic factors have materially increased, as has the turbidity. A striking feature is the increase in the percentage of moisture, denoting sponge-like action on the part of the sand grains. The efficiency of the wash has materially lessened. In one case, at the bottom section of the bed, there is no efficiency. Everything points to a complete paralysis of the function of the wash. Examined through the microscope, it was observed that the grains were completely coated with brown mossy growths of sewage mould and fungi. Fruiting bodies were in evidence, and the strands of hyphæ were seen bound about several adjacent grains in such a way that the sand was consolidated into clots and mounds. Under such conditions as these, the wash-water would be ineffective at a 2-ft. or a 3-ft. vertical rise. The

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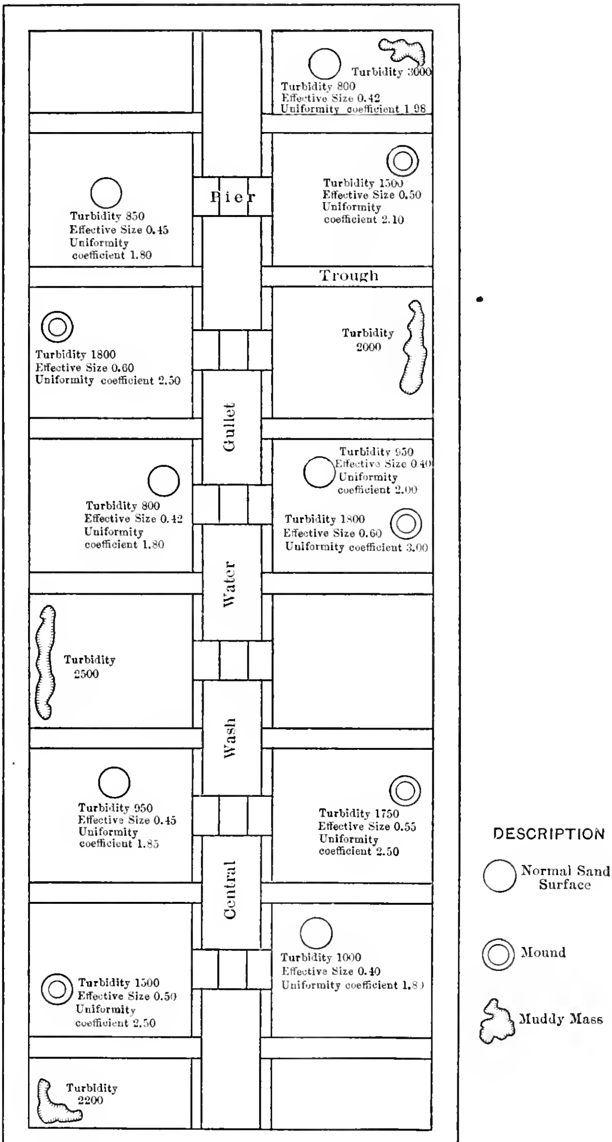

FIG. 23.

Mr. Willcomb. water, taking the course of least resistance, would pass around these masses of sand without disintegrating them, and, as a consequence, they would sink to the bottom of the bed and form the nucleus of a mud-ball or impervious zone.

Fig. 23 is a diagram of one of the rapid filters, with symbols to represent the condition of the sand. It will be noted that close to the wall the bed is badly silted up from top to bottom; the turbidity of the sand ranges from 2 000 to 3 000. Needless to say, these portions of the bed are inert, and neither filter nor wash. Adjacent to these mud-balls are mounds composed of sand of relatively high effective size and uniformity coefficient. It is at these points that the wash-water, diverted by the mud-balls, finally breaks through, and in so doing, carries much of the coarse gravel from the bottom of the bed to the surface, due to the greater velocity of the wash-water. If this happens in the proximity of a wash-water trough, sand is very likely to be carried into the sewer and lost. It is for this reason that the form or special devices attached to a trough are apt to be ineffectual, in the long run, in preventing the loss of sand. Theoretically, when the wash-water arrives at the point where the troughs are placed, the velocity is increased in direct proportion to the lessening of the superficial area by the surface of the troughs, and some sand is apt to be carried into them and lost. Some designers have attempted to correct this by modifying the shapes of the troughs and one finds all shapes in use, from semicircular sections to rectangular ones. However, owing to abnormal conditions of the sand and the sudden release of entrained air, the velocity of the wash-water is bound to increase at times, and carry the sand into the trough, regardless of its shape.

Mr. Pirnie. H. MALCOLM PIRNIE,* JUN. AM. SOC. C. E.—During the fall and winter of 1913, the speaker was working under the direction of Weston E. Fuller, M. Am. Soc. C. E., on the first design of a mechanical filtration plant for Ottawa, Ont., Canada. Certain fundamental principles pointed toward the adoption of a simple and inexpensive form of under-drains, and, to test their feasibility, an experimental filter conforming as nearly as possible to the Ottawa design was built in the Harvard University Hydraulic Laboratory under the direction of George C. Whipple, M. Am. Soc. C. E., Professor of Sanitary Engineering. A full report of the series of experiments with this filter, conducted by the speaker, is on file in the Harvard Engineering Library.

The ideal conditions to be attained in a rapid sand filter are: uniform rate of filtration over the entire sand area, and, during washing, uniform velocity of the rising wash-water over the entire area of the bed at the dividing plane between the gravel and the sand. The fact

* Springfield, Mass.

that the rate of application of the wash-water is many times as great as the rate of extraction of the filtered water through the same system of under-drains is the chief cause of the difficulties encountered in their design. To maintain the tendency for uniform rate of filtration over the entire area, it is necessary to cause an appreciable loss of head at the entrance of the water into the drains, and this is accomplished by restricting the size of the distributed openings. When a high rate of wash is applied, the velocity through these same openings is as much as ten times that of filtration, and its tendency to cause unequal velocities and currents must be destroyed within the few inches of gravel below the sand, otherwise there may be in spots a velocity high enough to raise the fine gravel, and it will settle back where the velocity is less and leave openings for the sand to enter the voids of the coarser gravel, and, once in the coarser gravel, the sand will easily wash down to the drains, where it will clog small openings in strainer systems. If ideal conditions of filtration and wash can be realized, no sand will penetrate into the gravel, and the necessity for expensive fine strainers will be eliminated. The design adopted for Ottawa, a similar one now giving satisfaction in Watertown, N. Y., that used for Franklin Furnace, N. J., and that used in the experimental filter, approached these conditions so nearly that no tendency of the sand and gravel to mix was discovered. It consists of lateral pipes connected with the main collector, perforated with ½-in. holes at regular intervals on the under sides, to direct the force of the wash-water downward against the bottom of the filter box, and covered with from 18 to 20 in. of gravel, varying from coarse at the bottom to fine at the top, which serves to baffle and destroy the unequal velocities of the wash-water and support the sand bed during filtration. Mr. Pirnie.

The following is an extract from the report of the tests on the experimental filter. It describes the process of filtration as well as that of washing. One is dependent on the other, and must be observed in order to afford full explanation of what occurs.

Objects.—The objects of these tests were to determine:

1. The effect of washing on a mechanical filter built up with simplified forms and under-drains and different sizes and depths of sand and gravel, first with a water-wash alone, and second with a water-wash preceded by an air-wash;
2. The loss of head during washing;
3. The loss of head during filtration;
4. The intensity and depth of clogging in the sand bed.

Apparatus.—The mechanical filter used in these tests is in the Hydraulic Laboratory at Pierce Hall, Harvard University. As shown in Figs. 24 and 25, it is a wooden box, 2 ft. 11 in. wide, 6 ft. 1½ in. long, and 7 ft. 5 in. deep, fitted with glass windows, a galvanized-

Mr. Pirnie. iron gutter discharging through a sluice-gate into a waste pipe, and the necessary piping for influent, effluent, and wash-water. An adjustable overflow is connected with the filter. In one side of the box at suitable elevations are placed gauge-cocks with straight tubes for

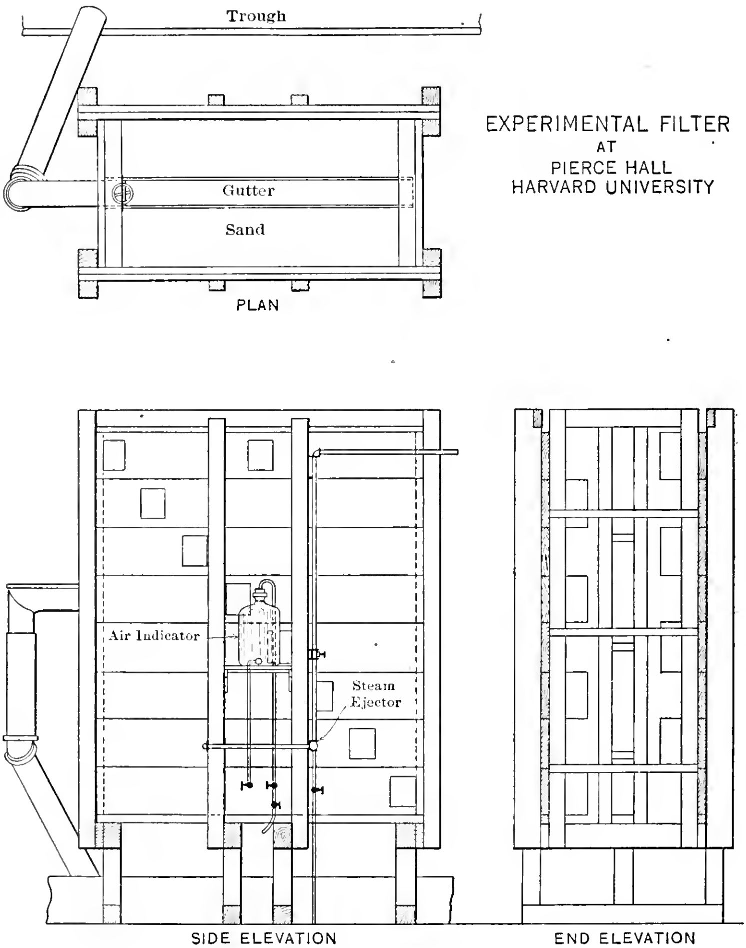

Fig. 24.

registering positive head, and U-tubes for registering negative head. A gauge tube and a pressure gauge are attached to the under-drains. The effluent discharges through a gate and a pipe which is closed by a water seal. All the gauges read in feet and inches below an arbitrary zero set at the top of the filter box.

The under-drains are formed by six lateral 2-in. wrought-iron pipes screwed into a 3-in. collector which discharges through the center of the floor into a 4-in. wrought-iron effluent and wash-water pipe. The free ends of the lateral pipes are capped, and each pipe has five ½-in. holes in its under side, placed as shown in Fig. 24, in order to direct the wash-water vertically downward to the floor. Between the laterals, and at the sides, wooden ridges direct the flow of the water through the first grade of gravel. Mr. Pirnie.

A ¼-in. pipe is tapped into the top of the main collector, and passes through the side of the box through a valve into a T, above which is another valve and below which is a waste pipe. A ¼-in. pipe extends from the upper valve into the top of a glass bottle set on a shelf several

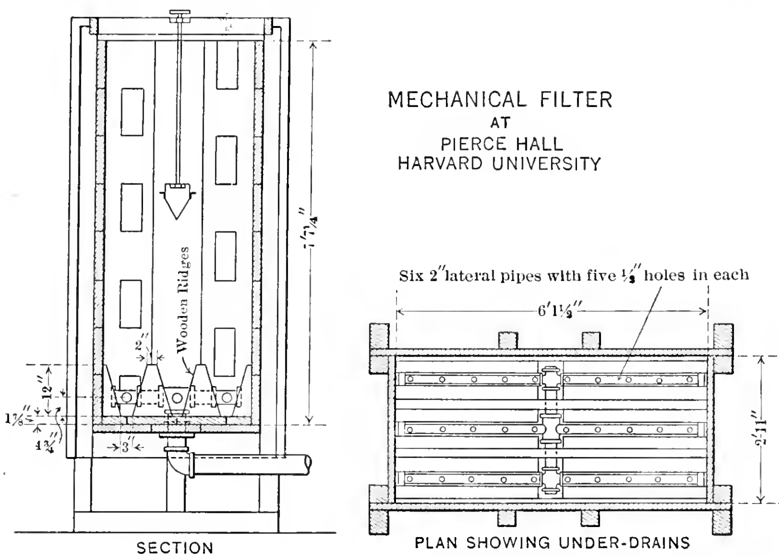

FIG. 25.

feet above the under-drains. The mouth of the bottle is closed with a rubber stopper. Another ¼-in. pipe, tapped into the bottom of the collector, passes through the side of the box, through a valve, and into the bottom of the glass bottle. This apparatus is filled with water at the beginning of a test, and indicates when air forms in the under-drains by allowing it to collect in the top of the bottle, water being forced out at the bottom.

Both the waste-wash and effluent pipes discharge into a trough below the filter, at one end of which is a weir. This is shown in Fig. 26. The water passing from this weir falls into one or the other of two weighing tanks, according to the way the controlling lever is placed. By these tanks the rate of wash and effluent discharge can be deter-

Mr. Pirnie. mined. The waste-valves at the bottoms of the tanks are controlled by levers above the weighing arms, and the discharge through them enters a concrete reservoir of considerable capacity in the sub-basement.

ARRANGEMENT OF PIPING AND APPARATUS FOR EXPERIMENTAL FILTERS. AT PIERCE HALL, HARVARD UNIVERSITY.

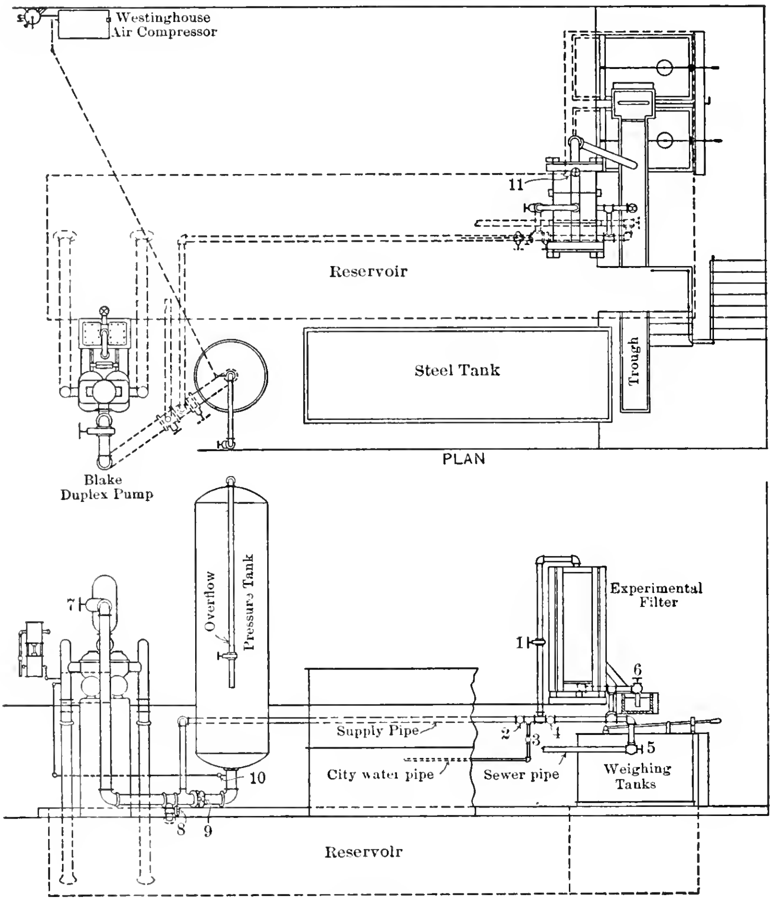

FIG. 26.

A Blake duplex steam pump, Fig. 26, with suction pipes in this reservoir, lifts the water and discharges it into the bottom of an air-tight pressure tank. At a sump in the discharge pipe from the pump to the tank are connected a waste-gate, discharging into the reservoir,

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and a 4-in. supply pipe for the filter. A ½-in. air line, from the Westinghouse direct-acting air compressor, enters the bottom of the tank through a valve. This arrangement makes possible a pressure service of either air or water. On the supply pipe under the filter are three gates, 2, 4, and 5, as shown in Fig. 26. A 2-in. supply pipe from the city main, with a gate (3), and the 4-in. filter influent pipe, are connected to the supply pipe between Gates 2 and 4. The influent pipe has a gate (1) above the floor. Between Gates 4 and 5 there is a 4-in. pipe which connects with the effluent pipe between the under-drains and the effluent gates (6). This pipe may be used to carry the wash-water or air to the under-drains, or the effluent to the sewer, as Gate 5 connects the supply pipe with the city sewer. By this system of piping either reservoir or city water can be used for influent or washing purposes.

Four different filter beds were placed and tested. The first two were built above a roughly constructed system of under-drains, and the third and fourth over those shown in Fig. 25.

General Method.—To determine the effect of water-wash on the filter bed, water was forced into the filter through the under-drains at different rates, and was observed through windows in the sides of the filter box. High rates of wash were applied gradually and suddenly, both to clogged and unclogged beds. The effect of air-wash was observed by forcing air through the under-drains into the filter, with the bed clogged and unclogged. Samples of sand, taken at different depths below the surface, were subjected to mechanical analysis, in order to determine the grading effect of the wash.

The loss of head in washing was ascertained by noting the pressures in the under-drains and at different elevations in the filter bed.

The loss of head during filtration was ascertained by allowing alum-treated water to enter the filter above the sand, flow through the bed, and discharge from the under-drains at determined rates, noting periodically the total loss of head, and the loss of head between different elevations in the bed.

An idea of the intensity and depth of clogging in the sand was obtained from the turbidity of sand samples scraped from the surface and at different depths below the surface of clogged beds. Throughout all the tests watch was kept at the windows in the filter box to observe everything that happened.

First Bed.—In the first strainer system the central laterals were 1 in. lower than the side laterals, their center line being 3.75 in. above the floor. The ridges (of ⅞-in. planks nailed to triangular braces) were so uneven that wash-water could enter under them and pass up through large cracks in the top. The laterals were 2-in. wrought-iron pipes, each having six ½-in. holes staggered ½ in. on each side of the lower center line. Over this system, to the depth of 6 in. above the floor, was

Mr. Pirnie. placed the first grade of gravel, passing a 1.5-mesh and retained on a 1-mesh screen. Practically all this gravel remained above the laterals. The second grade of gravel passed a 1-mesh and was retained on a 3-mesh screen. It was 3.5 in. deep, and was covered with 1 in. of gravel passing a 3-mesh and retained on a 10-mesh screen. The total depth of gravel was 10.5 in. Next came 4 in. of coarse sand, and then 28 in. of a mixture of Plum Island and bank sand.

Second Bed.—A change was made in the first strainer system, all the laterals being placed in the same plane, 4.75 in. above the floor. The same ridges were used. Care was taken to pack the first grade of gravel, which passed a 1.5-mesh and remained on a 1-mesh screen, around five of the laterals, one being left unpacked. The top of the first grade was 5.5 in. above the floor; the second grade (passing a 1-mesh and retained on a 3-mesh screen) was 6.25 in. deep, and the fourth grade (passing a 3-mesh and retained on a 10-mesh screen) was 1.25 in. deep. The total depth of the gravel was 13 in. Over this was placed 3.25 in. of coarse sand and 30.25 in. of Plum Island sand, effective size 0.57 mm. and uniformity coefficient 1.70.

Third Bed.—The strainer system and the ridges previously described (Fig. 24) were placed for this bed, and the largest size of gravel used in the first two beds was discarded. The first grade of gravel (passing a 1-mesh and retained on a 2-mesh screen) was packed carefully about the laterals, and enough was used to cover the ridges, bringing the surface to 12.5 in. above the floor. The second grade (passing a 2-mesh and retained on a 3-mesh screen) was 3 in. deep; the third (passing a 3-mesh and retained on an 8-mesh screen) was 2 in. deep; and the fourth (passing an 8-mesh and retained on a 10-mesh screen) was 1 in. deep, making the total depth of gravel 18.5 in. Above this was placed 21 in. of Plum Island sand, the effective size of which was 0.57 mm. and the uniformity coefficient 1.70.

Fourth Bed.—The sand of the third bed was removed, and 23⅜ in. of white Ipswich beach sand was substituted, having an effective size of 0.37 mm., and a uniformity coefficient of 1.65. The gravel and underdrains were the same as those for the third bed.

Details of Experiments.

The loss of head was determined at different periods during the run by reading all the gauges, and the rate was ascertained by weighing the effluent. When the head became negative at any one gauge, the positive-head gauge was shut off, and the negative-head gauge at the same elevation in the bed was turned on. A careful watch was kept on the sand bed through the windows and on the air indicator. In removing the sand beds, care was taken not to disturb the conditions at the surface of the gravel, and, when within a few inches of the gravel, the sand was scraped off carefully so that its condition in the parts of the bed away from the windows could be seen. Mr. Pirnie.

In replacing the filter bed, each grade of gravel was carefully leveled before the next grade was placed, and, when the last grade had been smoothed off, the filter was filled with water up to the gutter. The sand was dumped into the water, and settled on the gravel in piles, after which the wash was turned on, causing the bed to come to a uniform level.

First Bed.—On the speaker's arrival in Cambridge, February 3d, 1913, the first bed had already been placed. It was in poor condition, as the sand was mixed with the gravel. When the filter was running, sand escaped continuously from the effluent pipe. The bed was in such poor condition that no quantitative tests were made, but a few preliminary observations were taken in order to test out various parts of the apparatus. The filter was run at the rate of 125 000 000 gal. per acre per day, with alum applied to the influent, and the bed was watched through the windows. After running several hours, conditions of negative head were established, and the sand began to dry out about 6 in. below the surface, the latter being very dirty and covered with a slimy coat of alum flock. The sand was discolored from 3 to 4 in., varying from a marked stain at the surface to no noticeable color 4 in. below. The drying out in the sand increased, and the rate of filtration decreased rapidly. On closing the effluent gate suddenly air began to escape on the surface of the bed, giving an appearance like the start of an air-wash.

In a clogged condition the bed was washed with water applied suddenly at a rate of 2.6 ft. per min. The imprisoned air escaped first at several points near the sides of the box, and then from the surface of the sand. Then 6 in. of the bed rose in a mass, hit the bottom of the gutter, and broke. Marked streams of greatly agitated sand shot up through a bed of less agitated sand. These streams waved slightly in their upward course, but the points in the gravel where they originated were fixed, showing that the wash-water had a much greater velocity at these points than at others. Some of these streams were swifter than others, and when they reached the top of the sand it seemed to boil. The sand between the streams had a downward motion, and was caught at the gravel and shot upward in the currents. The velocity of wash was noticeably greater at the sides and ends of the box than in the middle.

After washing, the water was drawn from the filter and the surface inspected. About the ends and sides of the filter there were clearly marked spots of coarse sand which were 5 or 10 sq. in. in area and formed the tops of shafts of coarse sand extending vertically to the gravel. These shafts had been formed at places in the bed where there

Mr. Pirnie. was higher velocity of wash-water. After experimenting with this bed long enough to obtain a clear idea of its imperfections, it was taken out.

Second Bed.—After the gravel and 3.25 in. of coarse sand had been put in place, a wash of 2.5 ft. per min. was turned on. The agitation seemed to be greater at the ends of the box than in the main part of the bed. The greatest agitation was over the lateral which had been left unpacked in setting up the bed. When all the sand was placed in the bed and the wash was turned on, a very pronounced stream of swiftly moving sand extended upward from the top of the gravel directly over the unpacked lateral. It was accompanied by a violent boiling at the surface. There were other streams which were not so marked, and between them the sand descended slowly, only to be caught and shot up again by the currents. The streams over the packed laterals seemed to be very uniform in upward velocity, and their courses shifted back and forth on the way to the surface. On the whole, the wash was more uniform than in the first bed, but did not appear to be uniform enough to insure against the mixing of sand with the gravel.

After the wash the filter was drained and the surface of the bed examined. The central part presented a smooth surface of fine sand, but, close to the sides, there were several small patches and one large one of coarse sand near the end over the unpacked lateral. These spots occurred wherever the velocity of the wash-water was greatest.

An explanation of what is meant by the term "negative head" will make its use clearer. A filter in operation has a given head of water above the sand bed and is discharging water through its under-drains at a given rate. As the water passes through the filter bed into the under-drains there is a loss of head due to eddies and frictional resistance which is equal to the difference between the head as registered on the top of the sand and that in the under-drains. Now, if the top few inches of the sand are clogged so that more head than that available above the surface is necessary to force water through at the given rate, the additional head is obtained from water below the clogged part of the bed, that is, the water below pulls on that above just enough to force it through the clogged portion at the given rate. In general, when the loss of head in passing the sand at a given point in the bed exceeds the head of water above that point, a suction exists equal to the difference between the total loss of head and the head available above that point. This suction is called the negative head at the point in question.

The dot and dash line cutting two of the curves (Fig. 27) gives for any point in the sand bed the total head of water above that point; hence, at any point, if the plotted loss of head falls to the right of this line the head is negative by the amount it falls to the right, and, if it falls to the left, the head is positive by the amount it falls to the

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left. As the loss of head in the lower part of the filter bed is constant for constant rates, and is only a fraction of the difference in elevation between the top and bottom of this part of the bed, some of this head may be used in pulling water through the top of the sand and still leave a positive head on the under-drains. Thus, a considerable negative head may exist just under the surface of the sand, though the head is still positive on the under-drains. Negative head in a filter is always at its maximum just under the clogged surface of the sand, and this is where air first begins to free itself from the passing water and fill the sand voids.

CURVES FOR LOSS OF HEAD TEST
FROM TABLE 5.
FEBRUARY 25TH, 1913.
Distribution of Loss at Different Periods during Run.

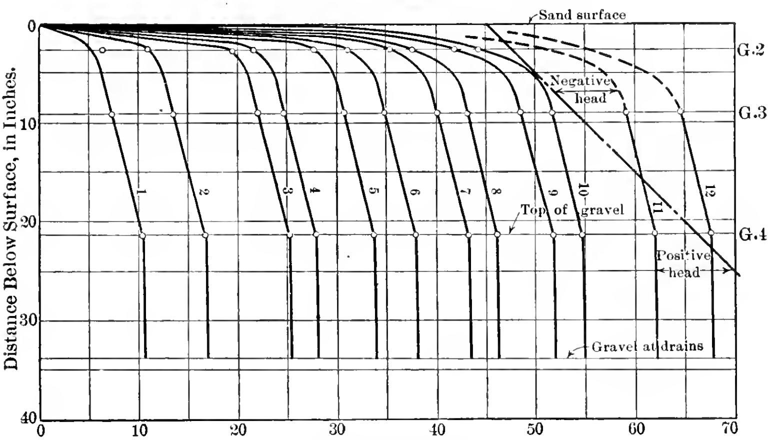

Fig. 27.

Water subjected to reduced pressure gives up air, which at first collects in little pockets in the sand voids. The surface coating of the sand, under the increasing pressure, breaks through in places from time to time, suddenly compressing an air pocket which breaks the surface in another place and escapes. Some flock is carried through the breaks, and forms another coating deeper in the bed. This action continues until the clogged portion of the sand is too strong to be broken, and then air accumulates in the sand voids until a cushion of air is formed between the clogged surface sand and the reservoir of water supplying the under-drains. As soon as this happens, the hydraulic unity of the filter is destroyed, and two separate actions begin, namely, the discharge of water above the sand through the clogged surface into rarified air, and the discharge from a body of water under a partial vacuum through the effluent-gate into water

Mr. Pirnie. under atmospheric pressure. Air continues to escape from the water that passes through the surface of the sand, and, expanding, reduces the available negative head by replacing with air part of the head on the under-drains. The discharge of water through the clogged surface decreases rapidly as the available negative head is reduced, and soon all the water in the lower part of the bed is discharged, leaving the bed filled with air and supporting above its clogged surface a reservoir of water. This rapid reduction in available negative head was due to the fact that the filter box was not absolutely tight, and air leaking in quickly reduced the vacuum when the head became negative in the vicinity of a leak. It is very important, therefore, to have a filter absolutely tight, if it is to be operated under negative head. The reduction of available negative head was much more rapid in the experimental filter than it would be in a tight concrete unit.

The curves showing the comparative losses of head in the top of the sand explain themselves. By far the greatest loss is in the top 1¼ in. of sand, and the rest of the variable loss takes place in less than the next 11½ in. The loss below Gauge 3 remained constant throughout the run.

An air-wash was applied to the filter in this clogged condition. The surface was completely broken up, and the dirt and top sand shot up into the water standing a little below the level of the gutter. Water penetrated only 4 or 5 in. into the bed, as the rising air kept it out of the lower portion, and therefore there was no disturbance between the sand and gravel. At the end of the air-wash the water above the sand was black with flock, and the surface was in mounds and valleys. The application of a water-wash cleared away all the dirt, and at the end left the bed smooth and clean.

Throughout the experiments with the second bed, no sand escaped from the effluent pipe, and, on taking out the bed, it was found to be in very good condition. In a few places, however, sand was mixed with the fine grade of gravel, and this was very markedly the case over the unpacked lateral near the end of the filter.

Third Bed.—After the gravel had been put in place, a wash of 2.5 ft. per min. was turned on. The water was clear enough to allow inspection of the surface of the fine gravel for a considerable distance back from the windows, and it was seen to be very uniformly agitated. There was no fixed point of boiling, thus showing the velocity of wash to be uniform throughout the main part of the bed. The agitation at the ends, however, appeared to be slightly greater. The sand was placed and washed at the same rate. Streams existed, as in the previous beds, but they were of equal velocity, and their points of origin at the top of the gravel shifted from time to time, showing the wash to be uniform. The condition of the surface of the gravel was excellent, no sand finding its way below it.

Table 5 shows the loss of head during the filtration test, in which the rate of flow of the effluent was kept nearly constant. The curves of Figs. 27 and 28, plotted from Table 5, show graphically the loss of head in passing through the bed at different periods during the test, and, also, the relative loss in the top 2.5 in. and the next 6.5 in. of the sand as the total loss increased. All the clogging took place in less than the first 9 in. of sand. Below this the loss of head remained constant. Nearly all the clogging was in the top 2.5 in., and, judging from the discoloration of the bed, did not extend to a greater depth than 4 in. below the surface. Mr. Pirnie.

TABLE 5.—LOSS OF HEAD TEST.
February 25th, 1913.

No.	Time: Hrs.	Time: Min.	Loss of Head, in Inches, Between Gauges: 1 and 2.	2 and 3.	3 and 4.	4 and 6.	Loss of Head, in Inches per Inch, Between Gauges: 1 and 2.	2 and 3.	3 and 4.	4 and 6.	Total loss of head, in inches.	Rate, in millions of gallons per acre, per day.
1	10	42	6¼	1	3¼	2½	2.5	0.2	Const.	Const.	13	120
2	11	7	11	2½	3¼	2¾	4.4	0.4	....	....	19½	123
3	12	4	19½	2½	3¼	2½	7.8	0.4	....	....	27¾	122
4	12	23	21⅞	2¾	3	2½	8.8	0.4	....	....	30⅛	123
5	1	8	27½	3¼	3	2½	11.0	0.5	....	....	36¼	126
6	1	36	31	3⅞	3	2¾	12.4	0.6	....	....	40⅝	126
7	2	16	35¼	4¾	3¼	2¾	14.1	0.7	....	....	46	129
8	2	41	37½	5½	3⅛	2⅞	15.0	0.8	....	....	49	129
9	3	21	41¾	6¾	3¼	2¾	16.7	1.0	....	....	54½	126
10	3	45	44	7¾	3	2¾	17.6	1.2	....	....	57½	126
11	4	5	59		3¼	2¾	....	....	....	....	65	122†
12	4	16	64⅜		3¼	2¾	....	....	....	....	70⅜	122
13	4	34	71		3¼	2½	....	....	....	....	76¾	122‡
14	4	46	74¼		3½	2½	....	....	....	....	80¼	122
15	4	56	76½		7¼*	2¾	....	....	....	....	86½	122

* There was no negative head gauge at Gauge 2, so that when this gauge became negative the losses between 1 and 3 were read.

† 2 and 3 negative.

‡ 4 negative.

Gauge 5 was out of order.
Gauge 2 is 2½ in. under sand surface.
Gauge 3 is 9 in. under sand surface.
Gauge 4 is 21¼ in. under sand surface.
Gauge 6 connected with effluent pipe above gate.
Gauge 4 is ⅝ in. below top of fourth grade of gravel.
Loss of head in gravel = ¼ in. at 125 000 000 gal. per day.

On this bed the time for a run was 6 hours 14 min., but on the second bed it was only 3 hours 21 min. The time factor is not of much use, as an unknown quantity of alum was applied to the influent, which varied in alkalinity; but it is obvious that, the longer the occurrence of negative head can be postponed, the longer the filter will run, and this was accomplished in the tests on the third bed by having a greater head of water above the sand than was available on the second bed. Near the end of the test the same conditions existed as in the tests on the second bed.

Mr. Pirnie. A sudden high rate of wash was turned on the bed after it was thoroughly clogged. The imprisoned air was compressed until it lifted and broke the surface, causing conditions similar to the start of an air-wash. Water rose through the gravel, lifted the sand in places, and then produced the condition of streams, previously described. No mixing of the sand and gravel was caused by the sudden application of the wash.

Table 6 shows the loss of head between given elevations in the bed with different rates of wash. The losses between 2 and 3 and 3 and 4 reach a maximum when the rate of wash is from 1.43 to 1.77 ft. per min. At rates higher than 1.77 ft. per min., the losses of head decreased. Between Gauges 4 and 5 in the gravel, the loss of

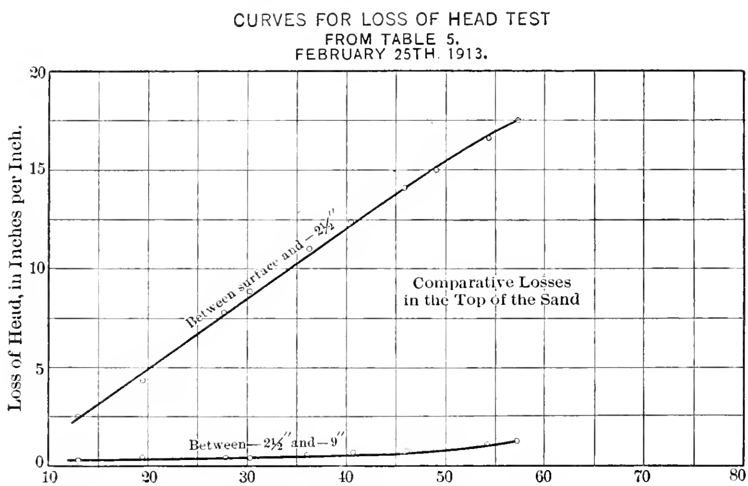

FIG. 28.

head increases steadily with the increase in rate of wash, which is true also between Gauges 5 and 6, as the water passes from the under-drains into the gravel. The perforations in the under-drains, as well as the voids in the gravel, remain constant during the wash. Therefore, as the velocity of wash increases, the losses of head in the under-drains and the gravel increase. It is different with the sand, however. The upward current of water exerts a frictional force on a sand grain, its intensity depending on the velocity of the water and the size and shape of the grain, and when this force exceeds the weight of the grain in water, it is carried up until a position is reached where the velocity, and therefore the frictional force, is less. Thus the finest grains of sand find their way to the top and become suspended in the rising column of wash-water just near enough together to

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cause the velocity required to keep them in their suspended positions. As the rate of wash is increased, heavier particles become suspended below the lighter ones, and the total voids in the sand are correspondingly increased. A measurement of the increase in voids may be obtained by multiplying the area of the filter by the distance the sand surface is raised. When the sand particles are suspended, there can be no greater scrubbing action caused by a higher rate of wash. The voids simply increase in size, allowing the velocity of the water passing the sand grains to remain the same. Therefore, for this sand, the maximum useful wash rate would seem to be 1.77 ft. per min. Greater rates increase the voids and do not increase the scrubbing action on the particles.

TABLE 6.—Loss of Head in Washing.

March 8th, 1913.

Rate, in feet per minute.	Distance sand surface raised, in inches.	Gauge Readings, in Inches.						Pressure gauge 7 lb. per square inch.	Loss of Head Between Gauges, in Inches.					Head outside under-drains 84.5 Gauge 5.	Head inside under-drains 84.5 Gauge 6.	Resultant head, in inches.
		1	2	3	4	5	6 computed from 1.		1 and 2.	2 and 3.	3 and 4.	4 and 5.	5 and 6.			
0.30	......	33½	31¾	27¾	21⅝	21½	18½	2.25	1¾	4	6⅛	⅛	3	63	66	3
0.76	......	33⅛	30⅝	25⅝	16¼	15¾	— 5½	3.25	2½	5	9⅜	½	21¼	68¾	90	21
1.15	......	33	30¼	25¼	15½	14¼	— 32	4.20	2¾	5	9¾	1¼	46	70¼	116	46
1.43	⅝	32⅞	30⅛	24⅞	14¾	13⅛	— 50	4.84	2¾	5¼	10⅛	1⅝	63	71⅜	134	63
1.77	......	32⅝	29⅝	24¼	14⅛	12½	— 96	6.50	3	5⅜	10⅛	1⅝	108	72	180	108
2.05	1⅞	31⅞	28½	23¼	13¼	11	— 134	7.90	3⅜	5¼	10	2¼	145	73½	218	145
2.42	3	28⅛	25	20⅛	10½	6¾	— 178	9.50	3⅛	4⅞	9⅝	3¾	185	77¾	262	195
2.76	......	24½	21	16	6	2	— 240	11.70	3½	5	10	4	242	82½	324	242

Pressure gauge has zero correction of + 1.5 lb. per sq. in., which has been applied in this table.

Gauge reading at under-drains = 84.5 in.
Gauge 5 is in gravel at drains 1¾ in. above center line.
Gauge 4 is in gravel ⅝ in. below top.
Gauge 3 is in sand 11⅝ in. above gravel.
Gauge 2 is in sand 18⅛ in. above gravel.
Gauge 1 is above sand.

At the end of the test, little lumps of sand, held together by some binding material, settled back on the surface. These were not present after an air-wash, but they are not broken up by a water-wash. They are suspended out of reach of the stirring action, and settle back unbroken on the surface after the wash. These masses reduce the clear surface of the bed. This may be desirable, inasmuch as it helps to form more quickly the desired filtering surface. If it is undesirable, the best way to break up these masses is with an air-wash.

Fig. 29 shows the grading of the sand in the third bed, due to washing. It is interesting as a proof of the way the sand is suspended by the upward current of water. On turning off the wash, Mr. Pirnie. the sand settles according to its size, the larger particles settling out first, and the smaller ones being deposited in successive layers on the coarser ones below them. The wash tends to make a mechanical separation of the entire bed of sand, and, because the sand curve is a straight line on a multiple logarithmic scale, in the natural sand, it is graded in the same way in a mechanical filter. The uniformity coefficient approaches unity at the surface, but, owing to foreign matter and irregularly shaped particles of sand, it is not unity. Deeper in the bed the stirring action of the streams mixes some larger particles with the sand, so that the uniformity coefficient is increased.

Fig. 30 gives a good indication of the depth and intensity of clogging in the third bed. From inspection of the bed after clogging it was apparent that the surface sand was discolored to a depth of 4 in., varying from a very marked discoloration at the surface to no noticeable color deeper than 4 in. below the surface. Comparing

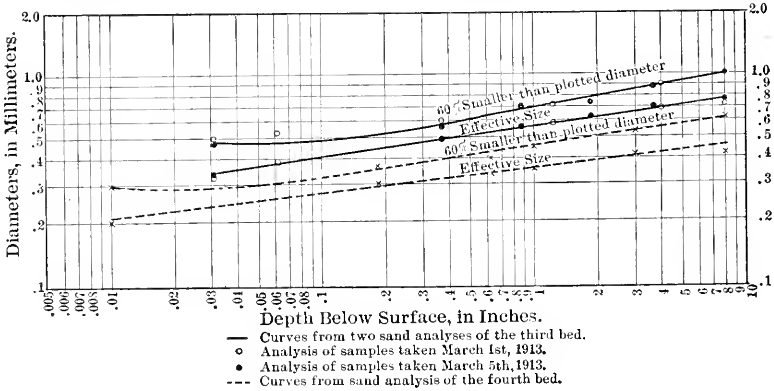

FIG. 29.

the turbidity curve of samples scraped from a washed bed with that curve for samples scraped from a clogged bed, it can be seen that the dirt does not penetrate below the upper 5 or 6 in. of the bed. This method does not give an accurate record of the intensity of clogging at different depths. Some of the dirt was in lumps, or adhered to the sand particles after drying, and therefore did not add to the turbidity of the water with which the sample was shaken. The curves, however, indicate clearly the way in which the clogging was distributed.

An air-wash was applied to the bed in an unclogged condition. At the start the bed was full of water, and the rising bubbles thoroughly mixed the sand and finest gravel. Almost instantly, however, the water was driven out of the fine gravel and sand by the rising air, causing all disturbances to cease except those at the surface of the sand. At the start the air pressure in the under-drains was 2 lb. per sq. in., and this was reduced to 1.5 lb. per sq. in. when the water was forced out of the sand. As the water stood at the level of the gutter when the wash was started, an overflow occurred, and carried with it a considerable quantity of sand. This was thoroughly mixed with the water, owing to the violent stirring action of the air bubbles. The overflow ceased as soon as the water had been expelled from the bed. This waste of sand could be avoided by drawing the water below the level of the gutter before starting an air-wash on an unclogged bed. It would not be necessary on a thoroughly clogged bed filled with air. Mr. Pirnie.

After the air-wash, a high-velocity water-wash was applied, driving the sand out of the fine gravel and leaving the bed in as good condition as it was before the test. The little masses of sand which existed after a water-wash alone were not present after this test, showing that an air-wash preceding a water-wash is the more thorough method of cleaning the sand.

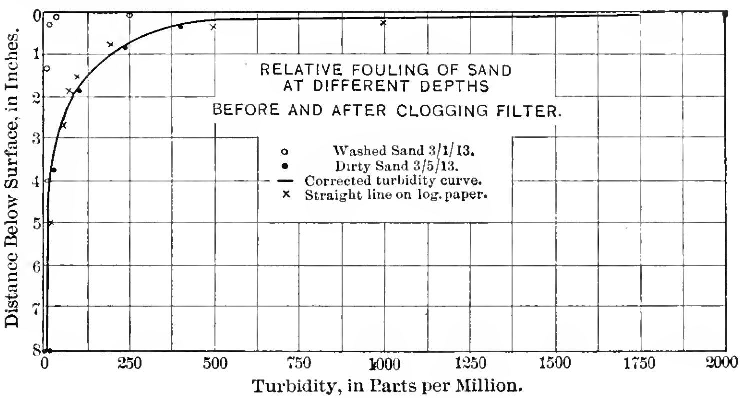

FIG. 30.

When the sand of the third bed was removed, the gravel everywhere was found to be in the same condition as when placed. No sand was mixed with it. Considering the fact that all possible variations of washing were used without producing permanent bad effects, this form of bed was considered satisfactory.

Fourth Bed.—When the Ipswich Beach sand had been placed in the filter, a water-wash was applied to grade it out. The desired effect was produced in this bed with a considerably lower rate of wash than was necessary to produce the same effect on the third bed. A few shells and some gravel separated from the sand, and formed on top of the gravel originally in the filter. The sand was graded according to size above it.

All the clogging took place in less than the upper 5.25 in. and most of it took place in the upper 0.5 in. Negative head occurred in the same way, and with the same effect as in the other three beds.

Mr. Pirnie. The run was of much shorter duration, owing to the fineness of the sand used. The discoloration in the sand extended from ½ to ¾ in. below the surface, giving a visible measurement of the depth of clogging. This was about one-sixth as great as the depth of clogging in the third bed.

The top 8 in. of sand was suspended with a wash rate of 1.15 ft. per min., a condition which was not produced on the third bed until a wash rate of more than 2.5 ft. per min. was used. As described under the third bed, greater rates of wash than that necessary to suspend the sand produced little additional cleansing action. Therefore, for the sand used in the fourth bed a maximum rate of 1 ft. per min. would seem to be more than ample.

A high-velocity wash applied suddenly to this bed lifted it bodily from the gravel before it broke up and began the stream action in the sand. No sudden washes with air or water seemed to affect seriously the condition of the boundary between the sand and gravel. The air-wash applied to the unclogged bed produced the most serious results. These were apparently remedied by the application of the high-velocity water-wash.

Fig. 29 demonstrates the grading of sand in the fourth bed due to washing. By comparing the curves a good idea may be had of the relative sizes of the sand in the third and fourth beds.

Figs. 31 and 32 show the effect of washing on sand placed in a mechanical filter. When the sand is first placed in the filter the effective size and uniformity coefficient are the same at all elevations in the bed. The wash causes a mechanical separation of the different sizes. The finest grains are forced to the surface, and the larger ones are adjusted in layers below the surface according to size.

Conclusions.—If a filter can be constructed so that the wash-water has a uniform velocity when it passes from the gravel into the sand, there will be no tendency of the gravel and sand to mix. This condition was so nearly attained in the third and fourth beds that the sand remained above the gravel after very high rates of wash had been suddenly applied and shut off. The tendency toward a slightly greater velocity of wash at the ends of the filter than in the main part of the bed was probably caused largely by the smoothness of the walls. The gravel between the ridges conducted the water with little loss of head to the ends, where there was less resistance afforded by the sand against the smooth filter walls than by the sand in other portions of the bed. There is no reason for building ridges parallel to the under-drains and not perpendicular to them. The tendency toward unequal velocities in one direction is as great as in another. Thus, if ridges are to serve their purpose completely, they should be constructed in the form of concentric rectangles about the center of the filter. The speaker believes that ridges are worse than useless. They

Mr. Pirnie.

occupy space which might better be filled with gravel and thus give a larger reservoir of voids at the bottom. This would make the upward velocity of the wash-water less at this elevation, and therefore allow a greater baffling effect in the lower gravel. It would be better, also, to use smaller gravel, in order to increase the loss of head through it, both in filtration and washing. The greater this loss of head the

GRADING OF THE SAND DUE TO WASHING.

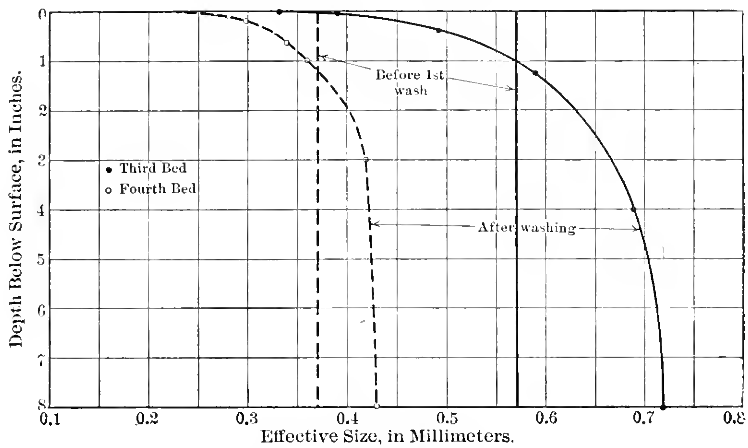

FIG. 31.

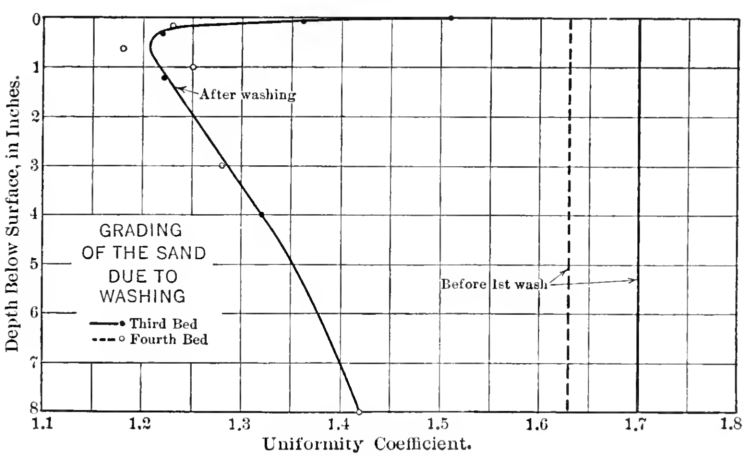

FIG. 32.

nearer are the ideal conditions of uniform rates of filtration and wash realized. The lowest layer of gravel needs to be just large enough not to enter or plug the openings in the under-drains, and the top layer should be a considerable thickness of fine gravel, just large enough not to be disturbed by the adopted maximum rate of wash.

Mr. Pirnie. The sand next to the top of the gravel should be only slightly smaller than the gravel itself. The sides of the filter should be rough, in order to increase the friction and remove the possibility of unequal velocities of wash.

The strainer system, Fig. 25, is excellent, and, if covered with from 18 to 24 in. of gravel ranging in sizes from coarse at the bottom to fine at the top, should produce a uniform velocity of wash through the sand.

Water-wash, when the rate is high enough to suspend the sand grains, grades the sand according to size. The finest sand is on the top, and the successive lower layers are each coarser than those above.

The wash tests on the third and fourth beds indicate that, for sands of different effective sizes, there are different effective rates of wash. Higher rates give little or no additional scrubbing effect, but may be high enough to carry away the lumps which are formed in some filters.

Air-wash is necessary to break up lumps that form on the surface of the sand. A very high-velocity water-wash will not do this, although, if high enough, it will get rid of some of the lumps by washing them into the gutters. If the sand and gravel are filled with air before an air-wash is applied, no disturbance is caused, except in the top few inches of the sand, and this produces no mixing of the sand and gravel. If, however, the bed is filled with water at the start of the air-wash, the rising bubbles cause violent eddies which mix the fine gravel and sand to an alarming extent before the water is driven out. The high-velocity water-wash regrades the sand and fine gravel, and therefore no permanent injury is done by the air-wash; but it is necessary to have a 3 or 4-in. thickness of fine gravel to make sure that no sand reaches the coarser gravel, and it is also necessary to follow an air-wash with a high-velocity water-wash to expel from the gravel the sand that has penetrated into it. A low-velocity water-wash will not force the sand out of the gravel, and, if an air-wash is continuously used on a filter, followed by a low-velocity water-wash, this sand may work its way down to the under-drains.

During filtration, all the loss of head due to clogging takes place in the top few inches of the sand. Therefore, negative head first occurs just under the clogged surface, and may exist there while the head is still positive on the under-drains. The maximum negative head is always just under the clogged surface of the sand. Therefore, air first begins to be freed from the water and to collect there. The water entering the under-drains has previously been subjected to a higher vacuum than can exist at the under-drains, and therefore should not release air when passing into them. Air that forms under the clogged surface reduces the available negative head by reducing the depth of the reservoir of water supplying the under-drains. A very small leak in the filter walls will supply air in larger quantities under the clogged surface, and therefore reduce the available negative head more rapidly. There is also an element of danger in operating under negative head if air leaks occur below the surface of the gravel. A procession of bubbles will begin to rise through the gravel and sand, collecting under the clogged surface, as soon as the head becomes negative at the leak. This will cause the same mixing between the gravel and sand as that which takes place at the start of an air-wash, and the mixing will continue. The water passing downward in the process of filtration will help to carry the sand down into the coarser gravel, where it will remain when the filter is washed. Each time, toward the end of a run, the disturbance will occur at the same place, and, in this way, a considerable quantity of sand may pass through the gravel to the under-drains. Therefore, it is much better to increase the head above the sand than to try to operate under a large negative head. Mr. Pirnie.

The depth of the sand is an important consideration in the design of mechanical filters. Every unnecessary inch of depth means the sacrifice of positive head equal to 1 in. plus the loss of head in passing through 1 in. of the unclogged portion of the sand. If a very uniform rate of filtration can be realized, it may be that the depth of sand can safely be reduced. Filtration at such a high rate is almost, if not entirely, a straining process. Therefore, very little benefit could be expected from longer contact with sand after the water has passed through the finest straining layers. In the coarsest sand used in these tests the depth of clogging was only 6 in. This indicates that a depth of sand of from 12 to 18 in. would be ample.

The results of the experiments left no doubt of the desirability of producing a uniform rate of wash over the entire bed. It is obvious that this may be brought about in much less space by directing the wash-water downward as it leaves the under-drains, thus breaking up the force of the individual streams against the solid filter floor. Sufficient gravel may be placed over the drains to quiet the eddies and currents remaining after the force of the streams has been broken. This depth may be much less than would be necessary if the wash-water streams were directed upward. In this case the gravel must break up the velocity of the streams as well as still the eddies and currents caused by them.

John H. Gregory,* M. Am. Soc. C. E.—The authors, as well as several of those who have discussed the paper, have presented data of especial value to engineers and others having to do with the design, construction, and operation of rapid sand filter plants. Had this information been available 15 years ago, when the present type of rapid sand filter was first being worked out, the task of the engineer engaged in designing such filters would have been greatly simplified. Mr. Gregory.

* New York City.

Mr. Gregory. With reference to the head required to wash filters, it should be noted that the experiments record the head necessary to pass the wash-water up through clean sand. The paper and discussion would be of still greater value if data could also be included showing what increased head, if any, is required to wash dirty filter sand, that is, sand in which the interstices have become clogged with dirt and other foreign matter in the actual process of filtration.

Mr. Barbour. F. A. BARBOUR,* M. AM. SOC. C. E.—This paper is of particular value to those interested in the design and operation of rapid sand filters. It makes available information of which but little has previously been made public, and which will prove valuable in future work, if used with due regard to the relation between the experimental conditions on which the data are based and those of practical operation.

In connection with the building of the filter plant at Akron, Ohio, an investigation of the effects of high-rate filter washes, similar to that described in the paper, was carried out, at the suggestion of the writer, by the New York Continental Jewell Filtration Company—the contractor on that work.

In the Akron filters, the Wheeler filter bottom was used, the right being granted, without payment of royalty by William Wheeler, M. Am. Soc. C. E., the designer and patentee. This filter floor consists of pryramidal depressions, 5.5 in. deep and 8.8 in. across the base, with a ¾-in. brass tube, 1.49 in. long, set at the apex, for the discharge of the filtered water or the admission of wash-water from the lateral channels or collectors below. The dimensions of the pyramidal depressions are such that five cement balls, 3 in. in diameter, one at the center at the apex of the ¾-in. opening, and four others in an upper layer, are in contact with each other and with the sides of the inverted pyramid. In the spaces between the upper four balls, nine marbles, each 1¼ in. in diameter, are laid, and on this a 6-in. layer of gravel is placed. Two views of this filter floor are presented, Fig. 33 showing several of the depressions, one empty and the others with one or more of the balls in place, and Fig. 34 showing a portion of the completed floor in one of the Akron filters.

The type of filter bottom just described has merit in low first cost, in freedom from dead spaces, and in the absence of metal parts subject to depreciation; but the most interesting feature is the complete distribution of high wash-water flows by the balls and marbles, so that with rates of wash up to and exceeding 4 ft. per min., there is no perceptible movement of a 6-in. gravel layer, even before the sand is placed, and therefore no need of any wire cloth, such as was used originally in the plant at Cincinnati.

* Boston, Mass.

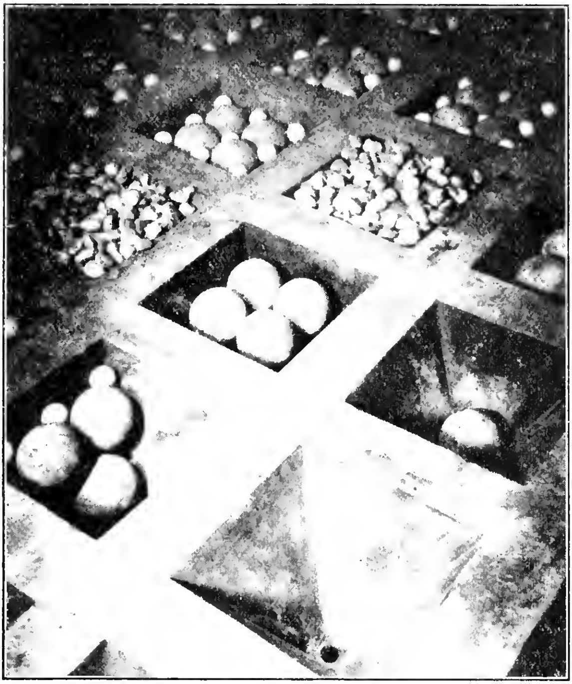

FIG. 33.—NEAR VIEW OF FILTER BOTTOM USED AT AKRON, OHIO, SHOWING METHOD OF PLACING BALLS AND MARBLES IN DEPRESSIONS.

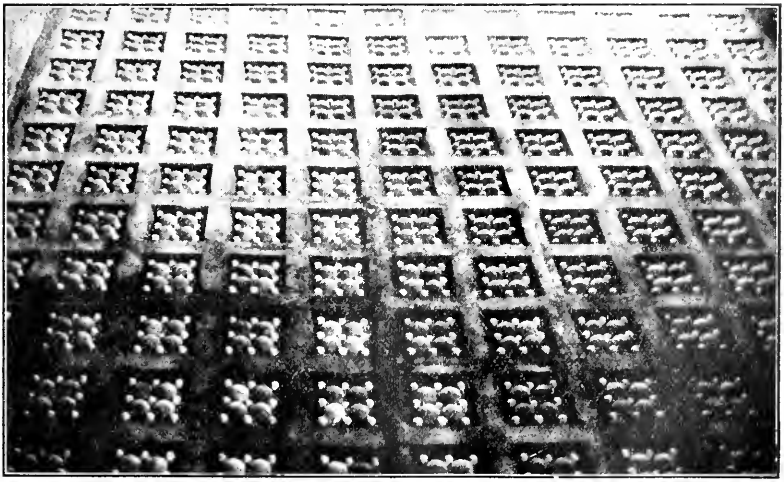

FIG. 34.—VIEW OF PORTION OF FILTER BOTTOM, AKRON, OHIO.

Mr. Barbour.

A small filter with a floor of this type had been constructed at Belfast, Me., previous to the Akron work, and R. S. Weston, M. Am. Soc. C. E., had demonstrated the possibilities of high-rate washes in an experimental filter. The contractor for the filter equipment at Akron, however, had no previous knowledge of this type of floor, and, at the suggestion of the writer, a small experimental filter, 2 ft. square, with a standard Wheeler floor of four depressions, overlaid by 6 in. of gravel and 30 in. of sand, with plate glass on two sides, was constructed. This was used in various studies of the loss of head, at different rates of wash, of the gradation in the sand grains resulting from high-rate washes, and of the relation between the rates of wash and the expansion and rise of sand.

The gravel consisted of three layers, the lowest $1\frac{1}{2}$ in. thick, of material passing a $\frac{3}{4}$-in. and held on $\frac{1}{2}$-in. mesh; the intermediate, $1\frac{1}{2}$ in. thick, of material passing a $\frac{1}{2}$-in. and held on a $\frac{3}{16}$-in. screen; and the top 3 in. of material passing a $\frac{3}{16}$-in. screen and held by a screen with 12 meshes per inch. The sand had an effective size of 0.40 mm. and a coefficient of uniformity of 1.60. The loss of head was determined by glass water columns.

Four curves are presented on Fig. 35, which show the loss of head under four conditions: through the $\frac{3}{4}$-in. opening and pyramidal depression without the balls in place, with the center ball in place, and with the five 3-in. balls in place, and the five 3-in. and nine $1\frac{1}{4}$-in. balls in place. It is interesting to note that the loss of head is less through the pyramidal depression with all balls in place than without any balls. The reason for this lesser loss of head with the balls in position is apparently due to the effect of the center ball in increasing the coefficient of discharge of the $\frac{3}{4}$-in. tube by the development of a vacuum at the point where this ball rests on the sides of the depression. That this is true was indicated in a rather interesting manner by an experiment made by Mr. Williamson, Chief Engineer of the New York Continental Jewell Filtration Company, under whose direction all the experiments herein described were carried out. A small, square, brass funnel, with a $\frac{1}{4}$-in. tube soldered to its apex, and with slopes the same as in the Wheeler filter bottom depressions, was prepared, and by a rubber tube the funnel was attached to a water faucet. In this square funnel a hollow, light, hard-rubber ball was placed, and water was run through the $\frac{1}{4}$-in. tube with a velocity of approximately 11 ft. per sec., or equivalent to that through the $\frac{3}{4}$-in. tubes in the Wheeler bottom when using a rate of wash of 24 in. per min. With this velocity, and with the funnel upright, the ball was not dislodged, and, after the water had been turned in for a few seconds, the ball remained in place with the funnel inverted. Two holes were then drilled on opposite sides of the ball and to one hole a $\frac{1}{16}$-in. rubber tube was attached. When the holes were placed directly on the center line of the funnel, water was forced through the ball and out through the tube, but when the ball

Mr. Barbour.

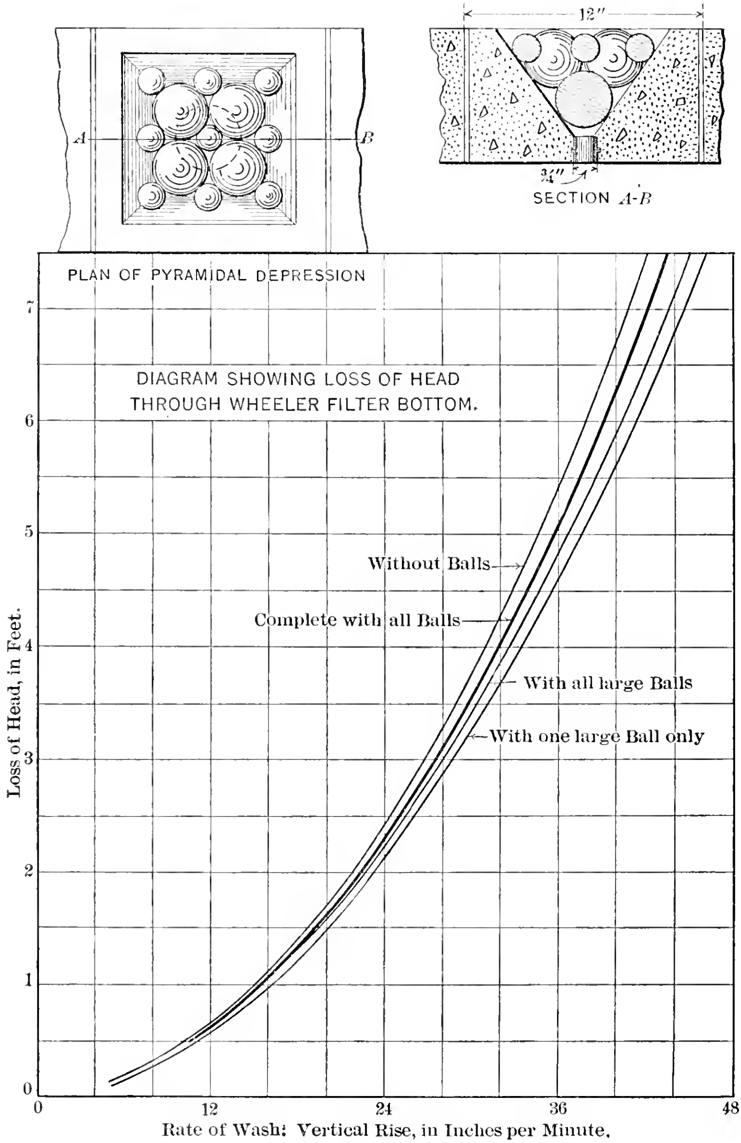

FIG. 35.

was turned so that the open hole was against the side of the funnel, water was drawn up through the ball from a beaker into which the small tube from the other hole in the ball had been placed, indicating that a vacuum existed at the point of contact between the ball and the side of the funnel. In this way the effect of the ball, in nullifying contraction in the tube at the base of the pyramidal depression, thus increasing the coefficient of discharge, is explained. Also, from this it may be fairly concluded that there will be no chattering or movement of the cement balls which might lead to wear and depreciation. The coefficient of discharge referred to the ¾-in. tube equals 0.92 with one ball in place, and 0.90 with all balls in place. The total area of the openings in the bottom of the depression equals 0.3 of 1% of the area of the filter, or practically the same relation as at Cincinnati. Mr. Barbour.

It will also be noted that the loss of head through the depressions and balls is but slightly greater than through the strainer plates at Cincinnati.

Fig. 36 shows the relation between rate of wash and loss of head in the filter bottom, through the 6-in. gravel layer, through the 30-in. layer of sand, and through the complete filter. The rate of wash in the experiments ranged from 10 to 42 in. per min. It will be noted that the total loss for a 24-in. wash is 4.86 ft., as compared with 4.20 ft. for the same wash at Cincinnati. The difference is largely accounted for by the greater loss through the sand, which averages 25% greater than that reported by Messrs. Ellms and Gettrust.

It will also be noted that, as found in Cincinnati, the greatest loss of head in washing filters occurs in the floor system and through the sand, and that the loss through the sand varies little with change of rate.

Although no precise determination of the loss of head during washing has yet been made at Akron, such observations as have been made indicate that the losses are somewhat less than shown by the experimental filters, and that this difference is more evident at the higher rates of wash.

Fig. 37 shows the relation between the upward velocity of wash and the expansion of the sand layer for a sand with an effective size of 0.40 mm. and 1.60 coefficient of uniformity. This diagram closely checks the curve of expansion for the sand with an effective size of 0.41 mm. shown on Fig. 19.

As pointed out by the authors, it is very necessary, in determining the height at which the gutters should be placed above the sand, to take into account the reduction in horizontal section by the gutters. Thus, at Akron, the horizontal area of the gutters is 30% of the total area of the filter, and the velocity of the wash-water equivalent to 24 in. per min., based on the area below the gutters, is equal to a velocity of 31.2 in. per min. at the plane of the gutters.

In any case, the height of the gutters should not be based too closely on experimentally determined expansions of clean sand. When

Mr. Barbour.

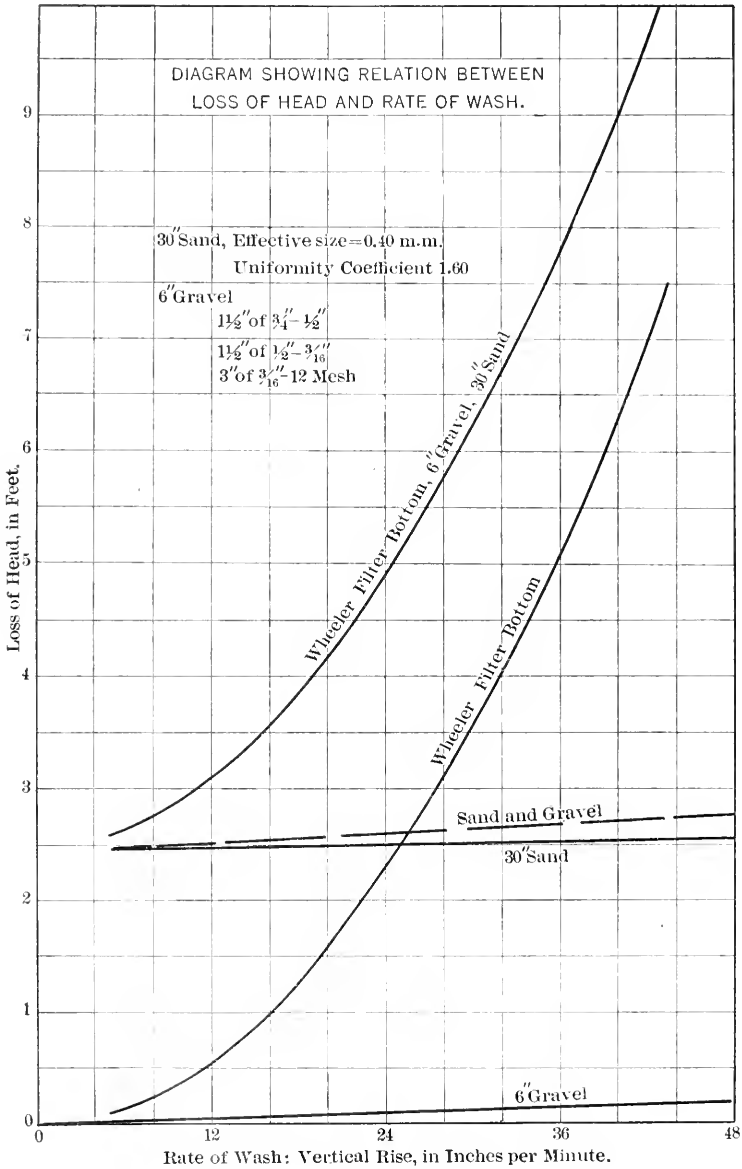

FIG. 36.

the Akron filters were put in service, the sand which as delivered averaged about 0.40 mm., with a coefficient of uniformity of 1.50, was given ten 5-min. washes at the rate of 24 in. per min. About 1½ in. of sand were scraped from the surface of the filters during these washes, and the surface was finally composed of a sand having an effective size of from 0.30 to 0.35 mm. For several months after the plant was put in service, the filters were washed at the rate of 24 in. Mr. Barbour.

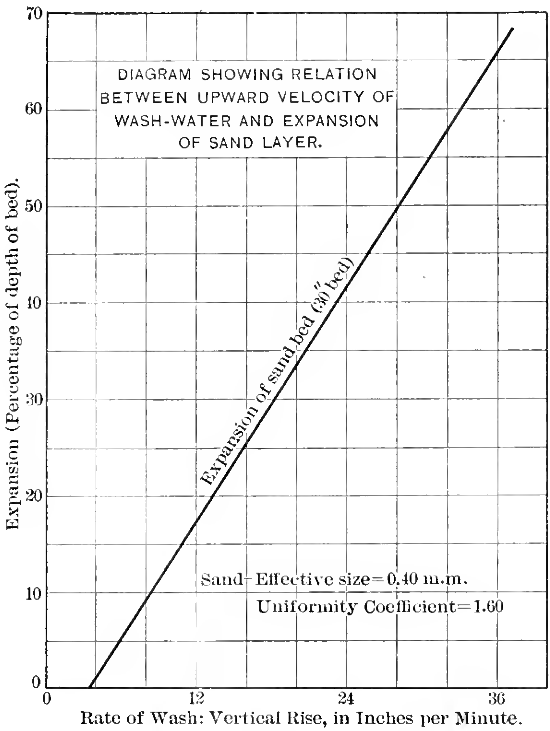

Fig. 37.

per min., without apparent loss of sand, but as the sand grains became coated with vegetable matter, the color of the water averaging 45, the expansion gradually increased, and it has been necessary, in order to avoid the loss of sand, to lower the rate of wash progressively until, at the present time, it is about 17 in. per min. This would suggest that, in determining the height of gutters from experimental results, a leeway should be allowed for the effect of the filtering material becoming dirty, and therefore lighter. In other words, data based on experiments with clean sand provide a basis of judgment rather than a means of precisely determining the necessary height of gutter.

Mr. Barbour.

In connection with the furnishing of the sand for the Akron filters, some interesting experiments on the effect of different rates of wash in grading the sand were made by Mr. Williamson. The specifications required that "the filter sand shall have an effective size of not less than 0.35 mm., nor more than 0.44 mm., and shall have a uniformity coefficient of not more than 1.65." After specifying ten washes of 5 min. each, at a rate of 24 in. per min., it was further required that "samples of sand taken from the sand layers after the sand had been washed in place, and especially from the upper inch, shall meet the requirements for size heretofore specified."

With the gradation resulting from a wash at the rate of 24 in. per min., this specification is equivalent to requiring that the upper inch shall have an effective size of not less than 0.35 mm., and the lower inch an effective size not greater than 0.44 mm. To determine whether the sand which it was proposed to use at Akron would fulfill these requirements after washing, the experimental filter already described was filled to a depth of 30 in., and washed at various rates, samples being taken at different depths by thin, brass cylinders inserted through holes drilled in the sides of the filter.

The sand, as delivered, had an effective size of 0.34 mm. and 1.82 coefficient of uniformity. After washing for 6 min. at a rate of 16.6 in. per min., the original 30 in. was increased to 32.2 in., and a sample from the top inch had an effective size of 0.17 mm. and a 1.41 coefficient of uniformity. Then 2 in. were scraped from the surface, and the filter was again washed at a rate of 17.7 in. per min. after which seven samples were taken at the depths shown in Part A of Table 7.

After taking Sample No. 9, the filter was washed several times at rates varying from 13 to 25 in. per min., and ½ in. was scraped from the surface, making a total of 2½ in. removed by scraping. Then 2¼ in. of the original sand were added, and the filter was washed four times at a rate of 26 in. per min., 1 in. of the surface sand being removed in two scrapings of ¾ and ¼ in. after the second and fourth washes, respectively. The filter was then given two 5-min. washings at 26 in. per min., and Samples Nos. 14 to 19 (Part B), Table 7, were collected.

The filter was then given two washes at 13.1 in. per min., and Samples Nos. 21 to 26 (Part C), Table 7, were collected.

Again, the sand was given a 10-min. wash at the rate of 10.5 in. per min., and Samples Nos. 27, to 32 (Part D), Table 7, were collected.

A comparison of the results noted in Table 7 makes it evident that the higher the rate, the greater the difference between the effective size of the top and bottom layers, and the lower the coefficient of uniformity of each layer; or, in other words, the higher the rate, the more nearly is the sand graded into layers in which the particles are of the same size. Also, it is shown that, with the sand used, gradation did not result from a wash as low as 10.5 in. per min. Mr. Barbour.

Gradation of the sand is immediately indicated by an increase in volume, and, when a low-rate wash is applied, the loss of gradation is shown at once by the lower elevation of the sand surface after washing.

TABLE 7.

Sample No.	Depth below surface, in inches.	Effective size, in millimeters.	Coefficient of uniformity.
Part A.			
3	0 - ½	0.24	1.25
4	½ - 1	0.32	1.22
5	1 - 2	0.34	1.23
6	2 - 3	0.35	1.23
7	3 - 4	0.36	1.28
8	4 - 5	0.40	1.40
9	7 - 8	0.45	1.40
Part B.			
14	1	0.30	1.27
15	7¼	0.45	1.27
16	13¼	0.48	1.37
17	19¼	0.48	1.37
18	24¼	0.48	1.37
19	30¾	0.48	1.37
Part C.			
21	1	0.35	1.51
22	6	0.42	1.45
23	12	0.42	1.45
24	18	0.42	1.45
25	23	0.42	1.45
26	29½	0.44	1.45
Part D.			
27	1	0.41	1.46
28	5¾	0.38	1.53
29	11¾	0.38	1.50
30	17¾	0.41	1.46
31	22¾	0.44	1.43
32	29¼	0.43	1.49

In the experiments just described, the total depth of sand placed in the filters was 32.5 in.; after removing 3½ in. by scraping, the depth of the sand bed, following a wash at the rate of 26 in. per min., was 30¾ in., and, after a wash at the rate of 10.5 in. per min., this depth was 29¼ in.

The gradation effected by high-rate washes suggests that a reasonable specification for filter sand would define the effective size of the

Mr. Barbour. surface layer after washing, and would permit a higher coefficient of uniformity than has been generally required in the past, or one which would result in the bottom layer of sand grading more evenly into the top layer of gravel.

Mr. Johnson. George A. Johnson,* M. Am. Soc. C. E. (by letter).—This paper presents some very instructive data based on experiments which obviously were made with painstaking care. Cincinnati was the first large city to adopt the high-velocity wash idea, although in numerous small plants this method has been practiced for many years. The New York sectional wash filter, which has been used for more than 20 years, embodies the same principles, and the old Hyatt shot-filled strainers were the forerunners of the type of filter bottom described by the authors. It was their purpose, also, to overcome the undesirable feature of gravel and sand mixing and to obtain even distribution of the wash-water; and these were the chief objects sought in the Cincinnati work. Hopper-shaped troughs, running lengthwise of the filter tank, the channels being covered with perforated brass strainer plates, is an idea first patented by Hyatt 17 years ago.

The upward velocities of flow of wash-water used by the authors, namely, 15 gal. per sq. ft. per min., are about double those commonly used where compressed air is applied preliminary to the actual washing of the filter. In some places, where relatively high-velocity washing is used—Akron, for example—a rate of 10.6 gal. per sq. ft. per min. appears to be giving satisfaction. At other places the wash-water is applied at a rate represented by about the mean of these two.

The omission of compressed air agitation, as an aid in the washing process, has never been looked on by the writer with unqualified approval. It is his belief that some form of scrubbing of the sand grains usually should precede the application of the wash-water. When treating waters containing large quantities of organic matter, the sand grains become heavily coated therewith, and, if these films are not rubbed off, the sand layer becomes very much lighter, and, even with moderately high wash-water velocities, considerable sand is lost during the washing process. Furthermore, the tendency is greater for mud balls to form, and these, being lighter than the sand, but heavy enough to resist moderately high wash-water velocities, are not removed from the filter, and, growing in size and weight, sink into the interior to clog the filter in spots and thus serve as a direct cause of unequal rates of filtration and wash-water application.

Air agitation, or mechanical stirring, serves to rub the sand grains together far more vigorously than the application of wash-water alone at high velocities. If it were not for the mud-ball feature, common in waters which contain large quantities of vegetable organic mat-

* New York City.

ter, the agitation afforded by the high-velocity wash probably would almost always prove adequate; but, in the treatment of some waters of this class, the writer believes that to dispense with the "scrubbing" phase of filter washing is simply paving the way for the complications previously noted. Mr. Johnson.

Mr. Barbour has mentioned this feature, as observed at the Akron plant, and that the sand beds, through the agency of the vegetable matter in the raw water, become more bulky. Consequently, they must become lighter, and the vertical rise of the sand layer during washing must be correspondingly greater. This must mean a waste of sand, unless the critical velocity of the applied wash-water is watched sharply and never allowed to become great enough to permit sand to be carried from the filter. Such restrictions as this may reduce the washing efficiency materially, by allowing balls of this vegetable matter to form and remain in the bed. The writer believes decidedly that, in the treatment of some waters, air agitation, preliminary to the washing process proper, is necessary.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

THE EFFECTS OF STRAINING STRUCTURAL STEEL AND WROUGHT IRON

Discussion.*

By Messrs. J. A. McCulloch, Ernst F. Jonson, and T. E. Stanton.

J. A. McCulloch,† Esq. (by letter).—The writer has seldom had the privilege of discussing a paper which accords so nearly with his own conclusions. Mr. McCulloch.

At times he has been inclined to urge the restriction of the term "viscosity" to that measure of internal resistance which increases in direct ratio to the velocity of relative motion. It is a property of all fluids, by virtue of which they resist motion produced by shearing force, and, necessarily, it ceases with the cessation of motion; that is, viscosity offers no static resistance. For limpid liquids, something is known of the laws of this resistance to shearing motion. Little is known of its laws where substances offer also (at the same time) elastic resistance.

However, all know well that the restricted dimensional meaning of this term is violated in the ordinary measurements of the viscosity of water and the thicker liquids. Moreover, its present use, as describing the plastic flow of ductile metals, is justified by the best authorities, for Lord Kelvin says: "The term plasticity implies no more than does viscosity".

The idea of a solid solution is difficult to comprehend, and does not at first appeal to our understanding, but the idea that many other substances are true fluids, even though they appear to be so solid as to be brittle to light blows, is equally difficult to grasp. Familiar examples are pitch and sealing wax. With elastic material, the case is even more difficult, because one finds it hard to conceive that the

* Discussion of the paper by Henry S. Prichard, M. Am. Soc. C. E., continued from March, 1916, *Proceedings*.

† McKeesport, Pa.

Mr. McCulloch. reversal of motion or lessening of stress changes the substance from liquid to solid. However, it is known that the conception of co-existing elastic and viscous actions has not led to experimentation which has yielded a satisfactory solution of the problem.* Difficulty in comprehending an idea is no refutation.

Misconception of the exhibition of elastic properties appears to be rather the rule than the exception. It may be due to false or partial education, or to the rush to train engineers in brief time, or to feeding "canned knowledge" in which no distinction is made between yield on primary loading and the recovery when the first load is released. For example, Pender gives:† "Ability to return to its original form after deformation is called elasticity"; and Kent states‡ that within the elastic limit, "* * * for such materials [iron and steel] the modulus [of elasticity] is practically constant * * ." Again, Kent§ quotes the late J. B. Johnson, M. Am. Soc. C. E., as follows: "The modulus of elasticity is the most constant * * * property of all engineering materials." The treatment of the subject is too brief, and is generally inadequate. Any one having accepted such ideas receives a shock when he turns to Kirkaldy's "Report L", or the reports on "Tests of Metals" at Watertown, and notes that the sets for iron and steel eye-bars run roughly from 2 to 17% of the elongation under the stresses applied before the elastic limit is reached. Fig. 7 illustrates the average percentage of sets on first loading of a few specimens of steel and wrought iron.

It may be that this dereliction of the elastic properties can be eliminated by a single loading to a slightly greater stress than that at which the sets were measured. Some tests|| which the writer has had to look after seem to indicate that several repetitions of stress are required; but, for steel, it is certain that the elastic properties are rendered nearly perfect by application of stress, and that this can be carried up to and beyond the elastic limit or yield point exhibited on primary loading. Under certain conditions, this perfecting of the elastic properties by application of high stress may enhance the utilitarian available strength remarkably.

Returning to the experiments that showed the necessity for more than one application of stress, it may be said that the measures were commercial testing, and had to be made with dispatch, so that what

* One of the most difficult features of the visco-elastic properties of steel is exhibited by the sudden tensile test which causes greater elongation than when similar material is pulled slowly. Indeed, Trouton and Rankine (*Philosophical Magazine*, Vol. 224, 1904, p. 536, etc.), speaking of their experiments on viscous traction, conclude that "the explanation of the phenomena must be sought for on altogether different lines from those based on mixed viscous and elastic action in the way commonly attempted."

† "American Handbook for Electrical Engineers," p. 1418.

‡ "Mechanical Engineers' Pocket-Book," p. 351.

§ *Ibid*, p. 352.

|| Not published.

is known as "Webber-effect" or *Nachwirkung* may have complicated the observations. Indeed, some few slowly conducted tests clearly indicated this "afterworking" of elastic recovery. Mr. McCulloch.

It would be wrong to dwell on this set on primary or first loading were it not for the fact that it is a common mistake, and ignorant men entrusted with the framing of specifications for steel frequently err by inserting a requirement that on removal of the first load no evidence thereof shall remain in the form of permanent set. In his

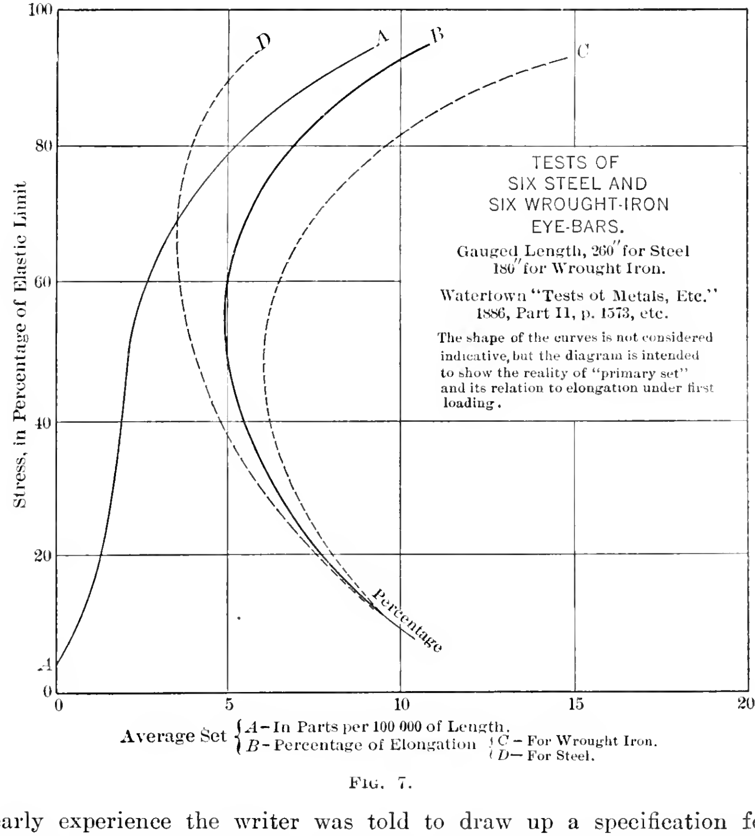

FIG. 7.

early experience the writer was told to draw up a specification for coiled (helical) steel springs. It was promptly rejected by all makers because of a requirement that there should be no set on first loading. For more than twenty years this erroneous idea of "no set on first application of load" has been specified, and the writer has become convinced that the proper and true idea of "primary set" has not been given the credence that is warranted by the ready accessibility of its proof. This type of set is non-indicative of quality. Philip

Mr. McCulloch.

Schidrowity, writing on "Rubber", says that even there it is not indicative, but that the rate of decrease in the area of the hysteresis loop on successive loadings does connote quality. Dr. Steinmetz has called attention to this "physical hysteresis" and its analogy to the electro-magnetic phenomenon of the same name.*

Under nearly every condition of the application of steel to its service, this set on first loading ("primary set") is wholly negligible. However, in the case of columns, the writer would attribute much of their notable dereliction on first loading to this primary set in conjunction with the variability of the elastic modulus where that property is measured by either yield or recovery from step to step of first loading, as shown by many of the Watertown tests.

One often hears expression of the erroneous idea that straining steel is injurious, but stress which does not over-strain puts steel in "a state of ease" where it acts as though it were nearly perfectly elastic. Even over-straining steel (if not carried to a ruinous extent), when allowed a reasonable time to recuperate before the next application of high (but lower) stress, will exhibit the characteristics of the "state of ease". The set will not be increased to more than that produced by the earlier strain; that is, repetitive loadings do not cause additional or cumulative distortion in steel. In this, steel is wholly unlike some of the soft metals, and, therefore, is vastly superior to them as a structural material.

The notable and great enhancement of the physical properties of steel by strain are well known, although many attempts have been made to ascribe the benefit to some more recondite phenomenon. Forging, rolling, drawing, etc., all improve steel, if the pressure is applied in a manner that causes a general flow; that is, when the pressure is not applied in a manner that causes high local stress.† When high local shears are caused, the general quality may be injured, but, by skillful application of this principle, Herr Mannesmann turned the failure of his planishing mill into the notable advance that bears his name as a method of producing hollow blooms which are of very high quality. Wire which has been drawn has been subjected to great traction at the same time that great external pressure was applied by the die. The stresses are far above the yield point, and the quality of the material is enhanced to a measure greater than the elimination that annealing involves when putting in shape for suspen-

* *Engineering News,* December 5th, 1912, p. 1051.

† Caution is required. The homogeneity of steel is not "perfect", but the imperfections (some visible under the microscope) are so small when compared with those of wrought iron, that there is some propriety in the use of the term "homogeneity". The imperfections of the two materials are so dissimilar that they belong to different orders of magnitude (to use mathematical language). Even the slag enclosures of wrought iron do not preclude benefit from stress. Dr. A. Leon, writing on "Irregular Strains Due to Non-Homogeneity of Materials" (Int. Assoc. for Testing Materials, No. 9, VIII, 1909), indicates that, although the material adjacent to cavities and enclosures may be at stresses vastly higher than the average applied stress, this localizing of stress largely disappears when ductile metals are strained beyond the yield point.

sion bridges. Although what is spoken of as heat treatment is doubtless mostly due to rapid cooling through the critical range, it has long been the writer's idea that the rapid cooling of the surface induces a great pressure on the interior, thus producing a benefit from stress, perhaps analogous to, but less profound than, fluid compression. Mr. McCulloch.

This fact of paramount importance remains, that steel is improved by strain. When the stress exceeds the yield point and is released for a sufficient time, the enhancement of the quality of the steel is immediately available and of great practical value, regardless of whether the stress is applied by the maker or user. High straining, if done in an ignorant fashion, may injure steel or other materials.

Ernst F. Jonson,* Assoc. M. Am. Soc. C. E.—There are two points in this paper on which the speaker wishes to comment. Mr. Jonson.

The author seems to conceive of the flow which takes place in ductile metals when stressed beyond the yield point as if it were due to a change in the metal from the solid to the liquid state. The energy required to bring about this change of state he seems to regard as a part of the work done by the load. This, however, is not in accordance with the facts. All the work done by the load previous to the beginning of flow is stored in the test piece as elastic energy, and, therefore, is not utilized in changing the state of the metal, as is the heat which is transformed into fluidity energy when a solid melts. One of the main distinctions between a solid and a liquid is the difference in their elastic limits. The elastic limit of the solid has a certain positive value, but that of a liquid is zero. As the temperature rises, the elastic limit diminishes until it becomes zero at the melting point. Flow takes place in solids, as well as in liquids, only when the shear exceeds the elastic limit; liquids flow under an infinitesimal shear because the elastic limit is zero; solids flow only when the shear is infinitesimally in excess of the elastic limit of the material.

The author's use of the words "sliding" and "slipping" in connection with flow seems to be unfortunate, because flow is something entirely different from slipping. Flow consists of an indefinitely extended, angular deformation, which is the resultant of a diagonal tension and a diagonal compression perpendicular to it. As soon as slipping takes place the specimen breaks and the flow stops. The fundamental difference between slipping and flow is best realized by remembering that the former is resisted by friction, and that the resistance produced by the latter is viscosity, two entirely different phenomena, following different laws; friction is a function of the pressure, and viscosity is independent of pressure and is a function of velocity and temperature.

Metals are not uniform in elastic limit in all their parts, and therefore they do not flow uniformly. The flow naturally begins in the par-

* New York City.

Mr. Jonson. ticles of the lowest elastic limit; but, owing to the fact that flow raises the elastic limit, the flow soon spreads to the particles of higher elastic limit. As the flow thus spreads throughout the mass of the metal, its quantity increases, and therefore the product of the elastic limit and the cross-sectional area increases at a decreasing rate until it ceases to increase and begins to decrease. The point at which this change takes place is the ultimate strength. When the elastic limit becomes equal to the cohesion of the material, no further stretching is possible and rupture occurs.

The author seems to be under the impression that shear is a peculiar kind of stress, an elemental stress, but shear is rather the resultant of two or three linear stresses acting at right angles to each other. A simple or two-dimension shear arises when two principal stresses of opposite kind but of the same magnitude act in the same point. A compound or three-dimension shear arises when two principal stresses of the same kind and magnitude, and a third principal stress of the opposite kind and twice the magnitude or greater, act in one point. Flow begins when the shear reaches the elastic limit, but rupture is not produced by shear. Tensile stress alone produces rupture, for rupture cannot be produced by compressive stress. The only condition under which pure compressive stress is possible is that of a specimen immersed in a liquid under hydrostatic pressure, and experiments have shown that rupture is not produced in this way. Hence, it follows that rupture is due to the tensile components. Since tensile or compressive stress may exist without shear, but no shear can exist without both tensile and compressive stress, it is evident that shear is not a simple form of stress.

Mr. Stanton. T. E. STANTON,* ESQ. (by letter).—The writer has read this paper with great interest, and considers it a valuable contribution to the literature on the strength of materials. There are one or two statements, however, to which he would like to call attention because he thinks that recent researches have shown that they need some modification. On page 71,† it is stated that in pieces subjected to alternate direct tension and compression, an increase in the rapidity of the alternations reduces the safe range of stress. Again, on page 96,† referring to the National Physical Laboratory tests on alternations of direct stress (Table 4), the author states:

"In structural members, however, as the frequency of the alternations is much less than in these tests, and as periods of rest are interspersed between alternations, it is fair to assume that the limits between which the stresses can alternate are greater than in the tests."

* Teddington, Middlesex, England.

† *Proceedings*, Am. Soc. C. E., for January, 1916.

Mr. Stanton.

These conclusions are apparently based on Reynolds and Smith's experiments,* in which a very large reduction in the safe range of stress was observed as the rate of alternation increases from 1 400 to 2 500 per min. The writer believes that it is now coming to be recognized that these results were peculiar to the testing machine used. At any rate, in the modified Wöhler method of test, which has been used extensively at the National Physical Laboratory during the last 10 years, no trace of a speed effect on the safe range of stress has been found below 2 and 2 200 alternations per minute. Further, periods of rest between series of alternations do not appear to have an appreciable effect on the total number of alternations for fracture. Again, in discussing the question of fatigue, on page 73,† Mr. Prichard states:

"* * * the greatest strength of steel or wrought iron under repeated stresses is beyond, and in some cases far beyond, the yield point."

Assuming that by the term "repeated stresses" is meant stresses varying from zero to an upper limit, the statement needs modification, as in many steels the maximum safe stress for repeated loadings from zero is well below the yield point. For example, in Mr. Bairstow's valuable paper‡ on the range of the elastic limits, with which Mr. Prichard does not seem to be familiar, experiments on an axle steel with a yield point of 24.9 tons per sq. in. showed that in repeated loadings from 0 to 23.2 tons per sq. in. no sign of want of elasticity occurred until after 6 000 loadings, when a permanent extension of the order of the yield took place.

The writer thinks it is not sufficiently recognized by engineers that the phenomenon of repeated loadings of a structure from zero to an upper limit is only a particular case of cyclical variations of stress in which the lower limit of stress is zero, and that it has been proved conclusively that the safe range of stress under such conditions is appreciably less than in the case of reversals of stress between equal values of tension and compression.

* *Phil. Trans.*, Royal Society, Vol. 199, p. 265.

† *Proceedings*, Am. Soc. C. E., for January, 1916.

‡ *Phil. Trans.*, Royal Society, Vol. 210, p. 35.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

THE FLOW OF WATER IN IRRIGATION CHANNELS
Discussion.*

By Messrs. H. B. Muckleston, Harold F. Gray, S. T. Harding, Allen Hazen, and R. B. Sleight.

H. B. Muckleston,† M. Am. Soc. C. E. (by letter).—The principal reason for the existence of discharge formulas is for purposes of design, so that the engineer can be reasonably sure that a canal or conduit will discharge at least the quantity required by its service. If this condition is satisfied, the designer has done all he can, and may rest content. Mr. Muckleston.

There have been a great many such formulas devised, ranging in complexity from the very simple Chezy expression through the awful Dubuat and Kutter equations, and back to the comparatively easy experimental formulas which seem to hold the stage at present. As the author very well states, something in the way of a coefficient to allow for varying degrees of roughness has to be assumed in any event, and it seems illogical to torture a formula with odd decimal exponents or complicated coefficients, when round figures would give results quite as close to the probable truth.

The author states that the value of the exponent p might be chosen as almost anything between $\frac{2}{3}$ and $\frac{3}{4}$, with little error. The writer pleads for a value of $\frac{2}{3}$, for the sole reason that the expression can then be solved with a slide rule, and, given a good memory and a duplex rule, the designer needs no tables, diagrams, or other aids. The writer also confesses to a decided preference for Manning's

* This discussion (of the paper by George Henry Ellis, Assoc. M. Am. Soc. C. E., published in February, 1916, *Proceedings*, and presented at the meeting of March 15th, 1916), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† Calgary, Alberta, Canada.

Mr. Muckleston. formula, because it retains the familiar symbol, n, for the roughness factor.

It has been the writer's experience that, for earthen channels at any rate, there is no constancy about any roughness factor. In one series of experimental determinations, at the same site, the value of n (Kutter) varied from 0.018 at a low stage to 0.0248 at nearly full supply. In another series, apparently made under similar conditions, but at a different site, the variations were in the opposite direction. Both series of experiments were made on a canal which had been in service 9 years.

The writer will admit that, in the case of lined channels, the designer can predict with somewhat more certainty that the assumed conditions of roughness will obtain in the finished structure, but, even then, variations in the roughness factor may be expected with varying stages.

The author makes the statement that "water runs in a canal by merely sliding down hill". It would be nearer the truth to say that it flows by falling over "itself". The early hydraulicians worked on the very convenient assumption that water flowed in a sort of series of concentric envelopes, each of them influencing and being influenced by its neighbor on each side. It was this theory that was responsible for the intangible dimension, R, which appears directly or indirectly in every formula since Chezy's. This dimension may have a physical existence in the case of a round pipe, and possibly, as a consequence, experimental results on such pipes seem to be more consistent among themselves, but for conduits of other shapes it would appear that a further factor is needed to allow for the shapes, or to correct for the use of R, a non-existent dimension. As far as the writer is aware, the only formula which contains such a factor is attributed to Professor Claxton Fidler, and is as follows:

$$\text{Log. } S = x\left(m + \text{log. } V - \frac{2}{3}\text{ log. } R\right) - 6.00,$$

in which m is a constant depending on shape, and x is a constant of roughness. He gives a demonstration of this formula,* with values of the coefficients, m and x, and also a modification of the formula for use with earthen channels.

Finally, it appears to the writer that, if experiments prove anything at all, it is that water in open and closed conduits does not follow the same law. In an open conduit, the slope is constant and the velocity depends on the hydraulic mean radius; in the closed conduit, the radius is constant and the velocity depends on the slope or hydraulic grade. If we take pipe experiments for pipe formulas and open-channel experiments for open-channel formulas, we shall be on surer ground, and our formulas should be more logical.

* "Calculations in Hydraulic Engineering."

HAROLD F. GRAY,* JUN. AM. SOC. C. E. (by letter).—The question of a relatively simple, yet reasonably accurate, formula for the flow of water in open channels is one which has engaged the attention of hydraulic engineers for a long time. Probably no formula has been so widely used as that of Ganguillet and Kutter, but this has always been open to considerable objection on account of its complexity, as well as certain inaccuracies. Bazin's formula is an improvement, in that it is simpler, but it is doubtful if it presents much greater accuracy than that of Kutter. It has not been used extensively by American engineers. The possibility of developing a simpler and satisfactory formula of the exponential type has been considered, particularly since the successful application of a formula of this type to the flow of water in pipes has accustomed engineers to its use. Mr. Gray.

The writer has been interested in this problem, and three years ago attempted to make comparisons between exponential formulas and those of Kutter and Bazin. From the exponential formula† used by the writer, he developed a diagram, Fig. 5, for its use. This diagram was used, in connection with diagrams for the Kutter and Bazin formulas, in determining what values of C were necessary, in order to obtain, for identical channels, the same velocity with the exponential formula as with the formulas of Kutter and of Bazin. Table 4 shows the variations in the coefficient necessary to bring the exponential formula into conformity with the Bazin formula. The tabular comparison for the Kutter formula has been lost.

In Table 4, Group I, for very smooth cement and planed boards, shows coefficients agreeing with Γ equals 0.109 in the Bazin formula; Group II, for smooth boards, etc., Γ equals 0.290; Group III, for smooth but dirty brick or concrete, Γ equals 0.500; Group IV, ashlar masonry, Γ equals 0.833; Group V, for earth canals in very good condition, Γ equals 1.54; Group VI, for earth canals in ordinary condition, Γ equals 2.35; Group VII, for earth canals exceptionally rough, Γ equals 3.17.

Examining the variation in coefficient within each of these groups, with varying slope and hydraulic radius, it will be seen that in Group I there is a very wide variation in coefficient with different values of R; the variation with the slope is comparatively much less in amount. In Group II the variation is less than in Group I for different values of R, the variation with different slopes being about the same as in Group I. The same remark holds true with Group III. In Group IV, for ashlar masonry, the coefficient is the most nearly constant of all groups, and it would appear from this that the formula should be fairly satisfactory for canals of such type. In Groups V, VI, and VII, there is increasing variation in coefficient for different values of R,

* Palo Alto, Cal.

† "American Civil Engineers' Pocket Book," 2d Ed., p. 858.

Mr. Gray.

TABLE 4.—APPROXIMATE VALUES OF C FOR USE WITH THE DIAGRAM, FIG. 5, FOR ESTIMATING THE FLOW OF WATER IN OPEN CHANNELS BY THE EXPONENTIAL FORMULA: $V = C\,R^{0.67}\,S^{0.54}$

I.—VERY SMOOTH CEMENT: PLANED BOARDS.

R	Slope.					
	0.0001	0.0004	0.001	0.003	0.01	0.05
0.5	215	210	205	200	195	185
1	205	200	190	185	175	165
2	190	180	170	165	160	150
3	180	170	160	155	150	140
5	165	155	150	140	135	130
7	155	145	140	135	125	120
10	145	135	130	125	120	115

II.—SMOOTH BOARDS, BRICK, CONCRETE, SEWER PIPE.

R	Slope.					
	0.0001	0.0004	0.001	0.003	0.01	0.05
0.5	175	170	165	160	155	145
1	170	165	160	155	150	140
2	165	160	155	150	140	130
3	160	150	145	140	135	125
5	150	145	140	135	130	120
7	145	135	135	130	120	110
10	140	130	125	120	115	105

III.—SMOOTH BUT DIRTY BRICK OR CONCRETE.

R	0.0001	0.0004	0.001	0.003	0.01	0.05
0.5	150	145	140	135	125	120
1	150	140	135	130	120	115
2	150	140	135	125	120	115
3	145	135	130	125	115	110
5	140	130	125	120	115	110
7	135	125	120	115	110	105
10	130	120	115	110	105	100

IV.—ASHLAR MASONRY.

R	0.0001	0.0004	0.001	0.003	0.01	0.05
0.5	115	110	105	100	100	100
1	120	110	110	105	100	100
2	120	115	115	110	100	100
3	125	120	115	110	105	100
5	125	115	110	110	105	100
7	120	115	110	110	100	100
10	115	110	110	105	100	100

V.—EARTH CANALS IN VERY GOOD CONDITION.

R	0.0001	0.0004	0.001	0.003	0.01	0.05
0.5	80	75	70	65	65	65
1	85	80	75	70	70	70
2	90	85	80	75	75	75
3	95	90	85	80	80	80
5	100	90	90	85	85	80
7	100	95	90	85	85	80
10	100	95	95	90	85	85

VI.—EARTH CANALS IN ORDINARY CONDITION.

R	0.0001	0.0004	0.001	0.003	0.01	0.05
0.5	65	60	55	50	50	50
1	70	65	60	55	55	55
2	70	65	65	60	60	60
3	75	70	70	65	65	65
5	80	75	75	70	70	65
7	85	80	75	70	70	65
10	85	80	80	75	70	65

VII.—EARTH CANALS EXCEPTIONALLY ROUGH.

R	0.0001	0.0004	0.001	0.003	0.01	0.05
0.5	50	45	40	35	30	25
1	55	50	45	40	40	35
2	60	55	50	50	50	45
3	65	60	55	55	55	50
5	70	65	60	60	60	55
7	75	65	65	65	60	55
10	75	70	65	65	60	55

the variation with different slopes being less than the variations for different values of R, except in Group VII, where the variation for different slopes is approximately the same as for variations for different values of R.

Unfortunately, the writer was not able to pursue the study of this matter beyond the points shown in Fig. 5 and Table 4. The paper by Mr. Ellis presents some tangible data on which to work, and it is to be hoped that some means can be found to overcome the discrepancies presented by previous formulas of the exponential type. In the use

Mr. Gray.

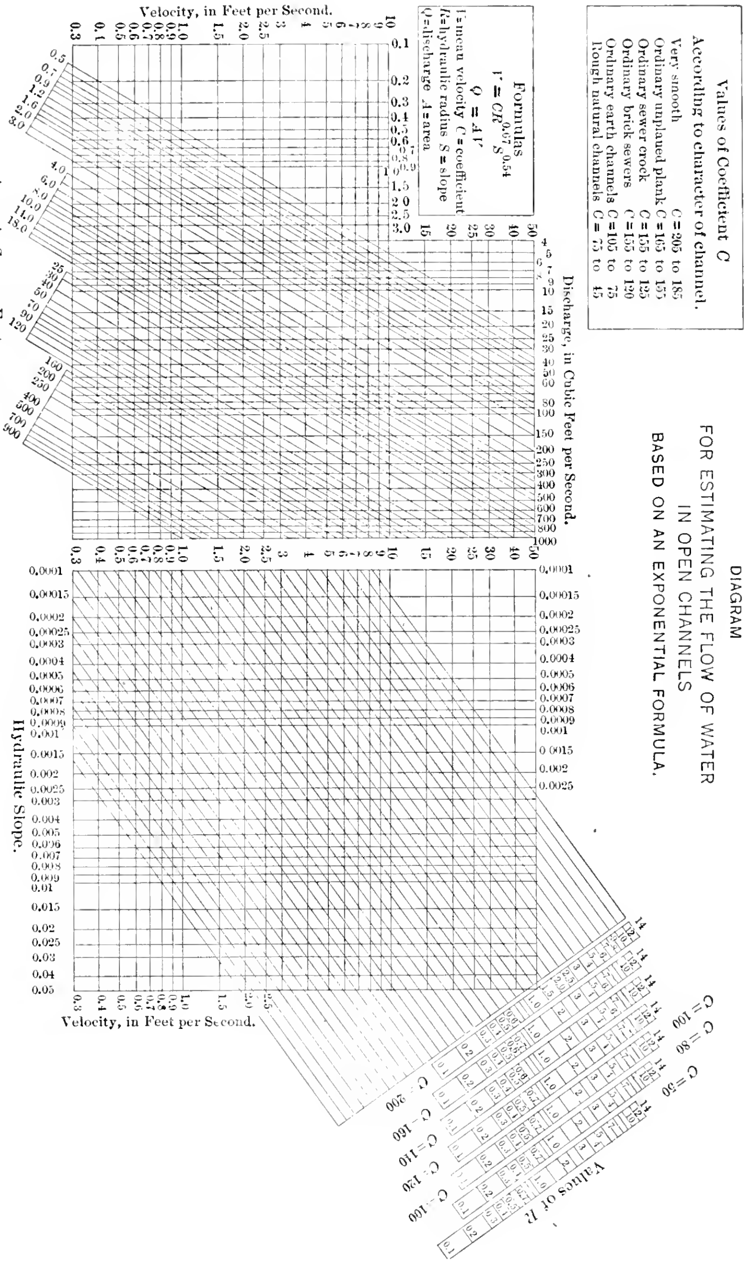
DIAGRAM
FOR ESTIMATING THE FLOW OF WATER
IN OPEN CHANNELS
BASED ON AN EXPONENTIAL FORMULA.
Values of Coefficient C
According to character of channel.
Very smooth C = 205 to 185
Ordinary unplaned plank C = 165 to 155
Ordinary sewer crock C = 155 to 125
Ordinary brick sewers C = 155 to 120
Ordinary earth channels C = 105 to 75
Rough natural channels C = 75 to 45
Formulas
$V = CR^{0.67} S^{0.54}$
$Q = AV$
V = mean velocity C = coefficient
R = hydraulic radius S = slope
Q = discharge A = area
Velocity, in Feet per Second.
Discharge, in Cubic Feet per Second.
Areas in Square Feet.
Hydraulic Slope.
Values of R
C = 200
C = 160
C = 140
C = 120
C = 100
C = 80
C = 60

FIG. 5.

Mr. Gray. of an exponential formula, however, so far as the writer can see, there does not appear to be any escape from the use of several formulas, with varying exponents for different types of channels, if accuracy within a reasonable allowable error is to be obtained. This may be avoided by the use of tables of coefficients, but in such case there is no apparent advantage over the Kutter and Bazin formulas, from a practical standpoint.

Mr. Harding. S. T. HARDING,* ASSOC. M. AM. SOC. C. E. (by letter).—The formula presented by the author is of the exponential form, and is suggested as a substitute for the well-known Kutter formula. The latter has been used so extensively, and the practice of comparing channel conditions on the basis of the value of n has become so large a part of the experience of those engaged in irrigation work, that any new formula must possess some definite advantage over Kutter's if it is to supplant it. Such an advantage may be either greater accuracy or greater convenience in use.

The author discusses some of the sources of error in experimental measurements on which any formula must be based. As the slope enters the result at only the 0.50th power in his formula, the error in the resulting velocity in the case cited by him would be only 3.7% on a canal with a slope as small as 0.0001. The writer made about 45 of the experiments given in *Bulletin No. 194*, on which the paper is based; and the levels were checked on these, so as to reduce the error in slope to much less than that percentage.

The accuracy of current-meter gaugings in large canals is necessarily uncertain, as the field conditions do not permit of the use of other methods which would give absolute checks. The flow and cross-section are more uniform than in many river gauging stations, and greater average accuracy should be attained. In connection with the investigations mentioned in *Bulletin No. 194*, experiments on the use of current meters in different methods of gauging were made at the same time, the particulars of which have been published.† These experiments give comparisons of the consistency of different methods of using current meters, rather than comparisons of any actual accuracy. They indicate that a consistency within 1 or 2% can be obtained. Current meters are similar to other engineering instruments; they may be used so as to give accurate results, or they may be handled so as to produce results only approximately correct, just as a transit may be handled so as to close a traverse within a minute of angle, or not within several minutes. The failure to secure accurate results is more commonly due to the conditions of use than to the fault of the instrument.

With any formula, greater accuracy cannot be expected than that with which the empirical coefficient can be selected. With Kutter's

* Berkeley, Cal.

† *Journal of Agricultural Research*, Vol. V, No. 6, November 8th, 1915.

formula, it is not usual to attempt to select the value of n within about 10 per cent. A 10% difference in the value of n in that formula gives a difference in discharge for a given cross-section of from 12 to 15%; and, to carry the same discharge on the same grade, requires about 8% increase in water cross-sectional area. With the large number of experiments now available, it should usually be possible to select coefficients and exponents approximating these limits for any formula which is correct in form. Mr. Harding.

Some evidence is presented in *Bulletin No. 194* tending to show that the value of n for a given channel varies with the depth of flow or the value of the hydraulic radius. This would indicate that Kutter's formula is not correct in form and does not represent exactly the law of flow in open channels. The variations, however, are not uniform. Johnston and Goodrich have presented a diagram* showing the variation of Kutter's n with the hydraulic radius, n becoming greater as the hydraulic radius diminishes. The values of n given are those generally adopted for earth channels, and are higher than those for artificial sections such as in wood or concrete. The actual experiments on which this diagram is based have not been published, as far as the writer is aware. It is difficult to see how dependable results on this point can be secured, except with channels of fixed and uniform cross-section and uniform surface. Such conditions are found in irrigation practice only in flumes or lined sections. In earth canals, the character of the wetted perimeter usually varies with the depth; grass and weeds may be submerged at high stages; the sides may have silt deposits; and the bottom may be clean or possibly somewhat gravelly. As the depth—and therefore value of the hydraulic radius—decreases, the value of n may easily vary, due to the greater relative importance of the character of the bottom of the canal. In *Bulletin No. 194* some data—also inconclusive—suggest an increase in the value of n with the discharge. In view of these conflicting and uncertain results, it seems safe to consider Kutter's formula as being sufficiently near to the theoretically correct form for all practical purposes.

Speaking broadly, Kutter's formula has no advantage, with reference to convenience in use, when compared with the various exponential formulas. With so many tables and curves available for the solution of Kutter's formula, actual computation in any case is unnecessary and unwarranted. The most important feature—relating to convenience in use—is the directness with which an engineer's experience in the selection of the empirical coefficient—such as n in Kutter's formula —can aid him in ascertaining the resulting velocity for any values of R and S. This can be done, at least at present for American engineers, most quickly and directly with Kutter's formula.

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* *Engineering Record,* Vol. 64, November 4th, 1911.

Mr. Harding.

Some of the formulas mentioned by the author, and based on present knowledge to a sufficient extent to warrant consideration, are Kutter's, Manning's and his own. In addition, there are Bazin's new or 1897 formula,

$$V = \frac{157.6}{1 + \frac{C}{\sqrt{R}}} \sqrt{R\,S},$$

and Williams' formula for open channels, $V = C\,R^{0.67}\,S^{0.54}$.

The value of C in Bazin's formula depends on the character of the wetted perimeter. Various values are given in different books, the details for earth canals being less explicit than for similar values for Kutter's n. The same may be said regarding the values of C in Williams' formula.

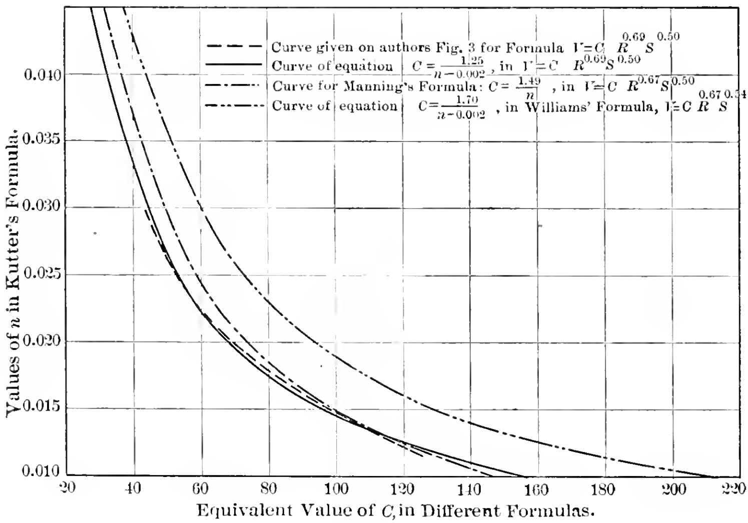

FIG. 6.

Owing to the general use of Kutter's n, in defining the character of the wetted perimeter, it is desirable to have some means of correlating n with the coefficients of these different formulas. Fig. 3 gives a basis for such correlation, and the author's plotting of this figure may be accepted. The range in the value of n, included in the different mean points plotted, is somewhat large, but further detail probably would not change the curve materially. That curve follows the equation, $C = \dfrac{1.25}{n - 0.002}$, quite closely, as shown in Fig. 6. The author's formula may then be written

$$V = \frac{1.25}{n - 0.002}\, R^{0.69}\, S^{0.50}.$$

Kutter's n enters into Manning's formula directly. The author's and Bazin's new formula can be equated as follows: Mr. Harding.

Author's formula: $$\frac{V}{R^{0.69}\,S^{0.50}} = \frac{1.25}{n - 0.002}$$

Bazin's formula: $$\frac{V}{R^{0.69}\,S^{0.50}} = \frac{157.6}{1 + \frac{C}{\sqrt{R}}}\;\frac{1}{R^{0.19}}.$$

This reduces to the equation

$$C = 126.1\,(n - 0.002)\,R^{0.31} - R^{0.50}.$$

The solution of this equation for various values of n and R is given in Table 5.

TABLE 5.—VALUES OF C IN BAZIN'S (1897) FORMULA FOR DIFFERENT VALUES OF KUTTER'S n AND THE HYDRAULIC RADIUS.

Mean hydraulic radius, R.	Values of C in Bazin's (1897) Formula for the Following Values of n in Kutter's Formula:					
	0.012	0.015	0.020	0.0225	0.025	0.030
0.5	0.31	0.62	1.13	1.38	1.64	2.14
1.0	0.26	0.64	1.27	1.59	1.90	2.53
2.0	0.17	0.62	1.40	1.79	2.18	2.96
3.0	0.062	0.60	1.50	1.94	2.38	3.28
4.0	— 0.063	0.52	1.49	1.98	2.46	3.43
6.0	— 0.25	0.40	1.50	2.05	2.61	3.70

The author suggests the need of using an exponent of S greater than 0.50. This is done in Williams' formula. The values of the exponent of S in the other formulas for closed conduits are so nearly the same as the 0.54 of Williams' formula that it appears safe to accept this value without elaborate investigation.

Using the experiments quoted by the author in the different classes —with some further subdivision—the value of C in the Williams' formula was computed by the writer for each experiment. Fig. 7 shows the means for the classes. The equation of the curve is $C = \frac{1.70}{n - 0.002}$, and it fits the data as closely as the conditions of determination and of use of such formulas warrant. It is also plotted on Fig. 6.

Williams' formula then becomes $V = \frac{1.70}{n - 0.002}\,R^{0.67}\,S^{0.54}$. This formula uses exponents of R and of S in general accordance with the other formulas of similar construction, and also with the indications of the author's results. If the use of any such exponential formula is considered preferable, it would appear that this one is the more logical. The computation of the 0.54th power of S requires

Mr. Harding. the use of logarithms; the 0.50th power can be secured directly with the ordinary slide-rule. However, the exponent, 0.67, of R requires logarithms for the complete solution of the equation, so that this disadvantage is not of importance.

Fig. 6 and Table 5 enable one to interpret the value of Kutter's n into any of the other formulas given. Such a relation permits one to think in terms of Kutter's n, and compute by whichever formula may be preferred.

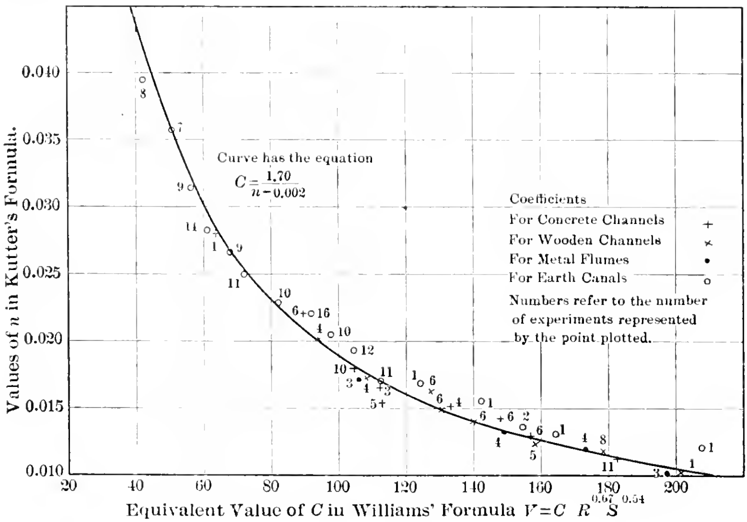

FIG. 7.

The values of the Chezy coefficient, C, for the different formulas, are given for certain values of R, n, and S in Table 6. Parts of this table are compiled from various sources and parts are computed for this purpose. These values are all reduced to the coefficient to be applied to $\sqrt{R\ S}$. The coefficient for Bazin's formula will depend somewhat on the basis of correlation of n and C. If that given in this discussion is used, the coefficients will be the same as for the Ellis formula, as they are derived from the same relation of n and C.

For the comparisons given, the Manning formula has coefficients higher than Kutter's for the larger values of n, but, for the lower values, the agreement is quite close; this is also indicated on Fig. 6. The variation seldom exceeds 10 per cent. The difference between the coefficients of the author's and Kutter's formulas varies with the different values of R, n, and S, the agreement usually being relatively good. On the steeper slopes, the coefficients from Williams' formula exceed those from Kutter's; on the flatter slopes the reverse is true.

Mr. Harding.

TABLE 6.—VALUE OF THE COEFFICIENT, C, IN THE FORMULA, $V = C\sqrt{RS}$, IN VARIOUS FORMULAS FOR DIFFERENT CONDITIONS.

Mean hydraulic radius.	n in Kutter's formula.	Value of C.									
		Manning's formula, all slopes.	Ellis' formula, all slopes.	Kutter's Formula.				Williams' Formula.			
				For Slopes of:				For Slopes of:			
				0.001	0.0005	0.0002	0.0001	0.001	0.0005	0.0002	0.0001
0.5	0.012	110.4	109.3	111.5	109.5	106.2	101.0	114.6	111.4	107.5	104.5
	0.015	88.3	84.0	85.0	83.5	80.7	76.6	88.0	85.8	82.4	80.2
	0.020	66.2	60.7	59.6	58.9	56.4	53.6	63.6	61.9	59.7	58.0
	0.0225	58.8	53.3	51.9	51.2	49.0	46.8	55.8	54.3	52.3	50.9
	0.025	53.0	47.6	45.6	44.8	43.2	41.0	49.8	48.4	46.7	45.4
	0.030	44.2	39.0	36.4	35.9	34.6	32.9	49.0	39.7	38.3	37.3
1.0	0.012	124.2	125.0	127.4	126.5	123.9	120.1	129.0	125.4	121.0	117.6
	0.015	99.3	96.2	99.1	98.5	96.1	93.1	99.2	96.5	93.0	90.3
	0.020	74.5	69.4	71.5	70.0	69.2	66.9	71.6	69.6	67.2	65.3
	0.0225	66.2	61.0	62.5	61.9	60.4	58.6	62.8	61.1	58.9	57.3
	0.025	59.6	54.4	55.4	54.9	53.6	51.8	56.0	54.5	52.6	51.1
	0.030	49.7	44.6	44.9	44.5	43.5	42.1	46.0	44.7	43.1	41.9
2.0	0.012	139.7	142.6	141.8	141.4	140.3	138.6	145.1	141.0	135.9	132.3
	0.015	111.7	109.7	112.3	111.8	110.9	109.4	111.5	108.5	104.5	101.7
	0.020	83.8	79.2	82.9	82.5	81.8	80.6	80.5	78.3	75.4	73.4
	0.0225	74.5	69.6	73.2	72.9	72.2	71.2	70.7	68.7	66.2	64.4
	0.025	67.1	62.0	65.5	65.2	64.6	63.7	63.0	61.3	59.1	57.5
	0.030	55.9	51.0	54.0	53.8	53.2	52.5	51.7	50.3	48.5	47.2
3.0	0.012	149.6	154.0	149.5	149.3	149.0	148.8	155.4	151.1	145.7	141.7
	0.015	119.7	118.4	119.2	119.1	119.0	118.7	119.5	116.1	112.0	109.0
	0.020	89.8	85.6	89.2	88.9	89.0	88.8	86.3	83.8	80.9	78.7
	0.0225	79.8	75.1	79.2	79.2	79.0	78.8	75.7	73.5	70.9	69.0
	0.025	71.8	66.9	71.2	71.2	71.0	70.9	67.5	65.6	63.3	61.6
	0.030	59.9	55.0	59.2	59.2	59.1	58.9	55.4	53.8	51.9	50.5
4.0	0.012	157.3	162.6	154.3	154.4	154.9	155.6	163.2	158.8	153.1	148.9
	0.015	125.7	125.0	124.1	124.0	124.5	125.0	125.5	122.1	117.7	114.5
	0.020	94.4	90.3	93.5	93.6	93.9	94.4	90.6	88.2	85.0	82.7
	0.0225	83.8	79.5	83.3	83.4	83.7	84.2	79.5	77.3	74.6	72.5
	0.025	75.4	70.7	75.1	75.2	75.5	76.0	70.8	69.0	66.5	64.7
	0.030	62.9	58.1	62.9	63.0	63.2	63.6	58.1	55.6	54.6	53.1
6.0	0.012	168.5	175.6	160.4	160.8	162.3	164.5	175.0	170.2	164.0	159.5
	0.015	134.7	135.1	130.5	130.3	131.5	133.5	134.5	130.8	126.0	122.6
	0.020	101.0	97.6	99.0	99.5	100.6	102.2	97.1	94.5	91.0	88.5
	0.0225	89.8	85.7	88.7	89.1	90.1	91.6	85.2	82.9	79.9	77.7
	0.025	80.8	76.4	80.4	80.8	81.7	83.1	76.0	73.9	71.3	69.3
	0.030	67.4	62.7	67.9	68.2	69.0	70.2	62.4	60.6	58.4	56.9

For all formulas, the agreement is generally within the probable error in the prediction as to the actual nature of the wetted perimeter, or the selection of the empirical coefficient. From the standpoint of results, there appears to be little choice between these formulas. Kutter's has the advantage of established usage, and Williams' perhaps has the advantage of more simple form. Exponential formulas can be developed in indefinite number, having small variations in the exponents and coefficient. It is very questionable if such differences are sufficiently great to warrant the inconvenience of their use. There may be an opportunity to bring together all available experimental

Mr. Harding. data in one general study of the best exponents to be used, but such data are voluminous, and the task would be laborious. The result would probably differ from Williams' formula to such a slight extent, if at all, as hardly to repay for the effort made.

Mr. Hazen. ALLEN HAZEN,* M. AM. SOC. C. E. (by letter).—This paper is a discussion by the author of experimental results collected by another. The author is not responsible for the experiments. The results obtained by his discussion are consistent among themselves to an extraordinary degree. The first impression is that there must be unusual merit in his procedure; further study, however, discloses a fallacy in it.

The results are consistent because of the method of classification of the data that is used as a preliminary to determining the formula which applies to each separated part. For this classification of data the Kutter formula has been used as a basis. Each section of the results thus separated is that which will produce the same value of n in the Kutter formula. The author, in reality, has found a series of exponential formulas each producing approximately the same results as the Kutter formula for a certain range. The effect of the procedure, therefore, is to demonstrate certain equivalents of the Kutter formula. It serves no other purpose. Nothing is brought out which substantiates the accuracy of the coefficients and exponents which are suggested by the author.

The method used to produce this extraordinary result is as follows: There were 269 experiments on irrigation ditches.† The data for each experiment were arranged to show, among other things, the value of n in the Kutter formula for that experiment. This is as far as Mr. Scobey carried the study. The author has taken Mr. Scobey's results and classified them according to the values of n. For the experiment in each section thus classified the value of n is nearly constant. The experiments in each section are then used to determine an exponential formula. The formula thus ascertained accounts for these particular experiments; that is to say, for those experiments in which a certain value of n is found. The exponential formula thus found corresponds approximately with the Kutter formula, with that value of n, and for the range covered. It would be impossible for it to do anything else.

The results reached by the author might have been reached more readily and with greater accuracy by a direct analysis of the Kutter formula. For instance, referring to the coefficients of the Kutter formula as tabulated by Trautwine,‡ for a slope of 0.001, which may be taken as representative of these experiments, the increase in the

* New York City.

† Described in *Bulletin No. 194*, U. S. Department of Agriculture, by Frederick C. Scobey, Assoc. M. Am. Soc. C. E.

‡ "Civil Engineer's Pocket-book", 19th Ed., p. 568.

coefficients in the table from 139 for $R = 1$ to 155 for $R = 2$ is as the 0.16th power of R. As R again comes into the calculation to the extent of the 0.50th power, by Kutter's formula, for these conditions the increase in velocity is as the 0.66th power of R. In the same way, for $n = 0.020$, this exponent becomes 0.73, and for $n = 0.030$ it becomes 0.75. Mr. Hazen.

Comparing these values with those found by the author and plotted in Fig. 4, the correspondence is seen to be striking. In other words, the author has found an average exponent of 0.69 simply because 0.69 gives approximately the same average increase for these experiments as would be given by the Kutter formula. There is no other basis for this conclusion. There is no analysis of the experimental results that indicates what the true exponents are, and it may be questioned whether the data in the paper are sufficient to make possible any close determination of their values.

In the same way coefficients in the several formulas found by the author may be compared with the coefficients for the Kutter formula in the Trautwine table as in Table 7.

TABLE 7.

Values of n.	Ellis. Fig. 3.	Trautwine. $S = 0.001$ $R = 1.$
0.012	123.7	122
0.013	114.0	116
0.015	98.4	99
0.017	86.0	86
0.020	70.0	71
0.030	44.4	45

The agreement of the coefficients ascertained by the author with those of the Kutter formula for the same values of n is no less striking than is the case with the exponents. It follows, for the same reason, and has no greater significance.

Those who wish to make use of the valuable data represented by this paper will do well to refer to the original publication, as the paper under discussion hardly does justice to it.

R. B. Sleight,* Esq. (by letter).—The writer has had occasion to investigate the flow of water in concrete-lined channels from the standpoint of the use of the exponential formula for velocity. The data on which this study was based are those in *Bulletin No. 194*, U. S. Department of Agriculture, by Frederick C. Scobey, Assoc. M. Am. Soc. C. E.; in *Bulletin No. 126*, U. S. Department of Agriculture, by Samuel Fortier, M. Am. Soc. C. E.; and in *Bulletin No. 194*, Colorado Agri- Mr. Sleight.

* Denver, Colo.

Mr. Sleight. cultural College Experiment Station, by Mr. V. M. Cone. An outline of the investigation and its results is offered in discussion of the paper by Mr. Ellis which has for its basic data *Bulletin No. 194* of the U. S. Department of Agriculture.

The writer has taken up only concrete-lined channels, and the expression for flow was assumed as

$$V = C_1 \; R^m \; S^n \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The exponents for R and S were not assumed arbitrarily in either case, but an attempt was made to work out both of them, and it is believed that this was successful for the exponent of S as well as for that of R. The work was done by graphical methods in all cases where possible.

For analysis, Equation (1) was divided into two parts:

$$V = B \; S^n, \text{ or } S = A \; V^{\frac{1}{n}} \ldots\ldots\ldots\ldots\ldots (a)$$

which contains the term, S, and

$$A \doteq k \; R^p \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (b)$$

to take care of the term, R.

A recombination then results in

$$S = k \; R^p \; V^{\frac{1}{n}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

with the first step in its investigation a study of $\frac{1}{n}$.

All the available data were plotted logarithmically. The experiments were divided into groups so that any one set or group would have but small variation in the value of R, for example, those with R less than 1.0 in one group, those with R from 1.0 to 1.5 in another group, etc. This is illustrated by Fig. 8. In this first analysis the values of S were plotted against values of V to get a numerical value for $\frac{1}{n}$, in the equation,

$$S = A \; V^{\frac{1}{n}}.$$

As the values of R cover a small range for any one group, other than the variables taken care of in this equation, the factor of friction (or whatever we may choose to call it) is the only variable left. The center of gravity line of the plotted points, S and V, for each group of representative canals was found, and $\frac{1}{n}$ was determined for that line. The following assumptions were then made: That the value as found for the group would approximate closely the true value of $\frac{1}{n}$ for any point or measurement in that group; that the arithmetical mean of these several values of the exponent (one for each group)

Mr. Sleight.

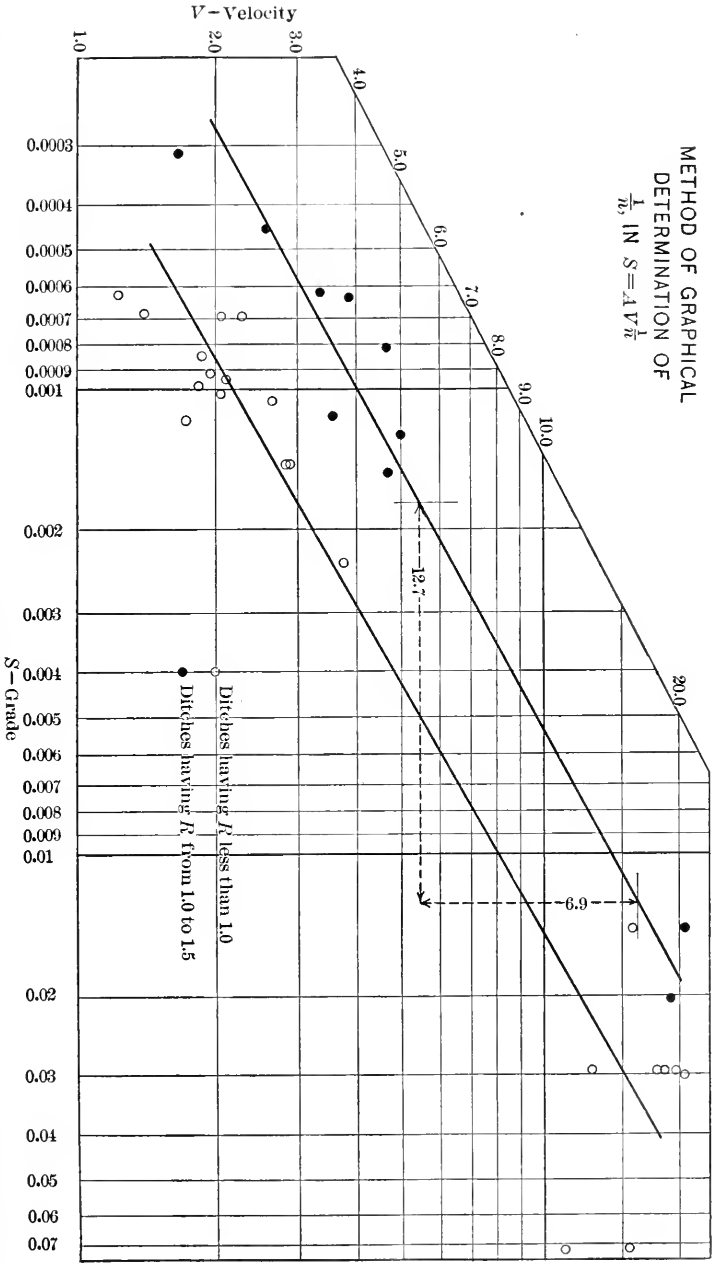

Fig. 8.

Mr. Sleight.

TABLE 8.—CHANNELS INVESTIGATED FOR

Reference.*	Curve No.	Canal and authority.	Experiment No. in *Bulletin No. 194*.	Discharge, in second-feet.	Slope, *S*.	Mean velocity, *V*.
194........	1	North Canal,	46	98.3	0.000639	3.02
		Bend, Ore.,	48	74.9	0.000729	2.87
		F. C. Scobey.	50	25.7	0.001021	2.04
194........	2	North Canal,	45	98.3	0.000525	2.94
		Bend, Ore.,	47	74.9	0.000692	2.85
		F. C. Scobey.	49	25.7	0.00095	2.10
194........	3	South Canal,	33	89.8	0.0718	15.52
		Uncompahgre,	34	59.7	0.0723	11.32
		V. M. Cone.	32	111.3	0.0015	4.71
Colo........	4	Long Pond Chute,		35.8	0.02879	12.87
		Fort Collins,		78.3	0.02968	18.26
		V. M. Cone.		100.4	0.02943	17.89
				104.5	0.02990	20.21
				122.9	0.02971	19.70
126........	5	Ridenbaugh,†	15	50.0	0.000325	2.45
		Boise,		103	0.00015	2.32
		U. S. R. S.		230	0.0002	3.35
				382	0.00024	3.99
				103	0.0003	2.45
				382	0.000168	4.08
				376	0.0003	4.32
				318	0.000315	4.15
126........	6	King Hill,		92.5	0.000187	2.06
		Idaho,		54.5	0.000452	2.54
		Don Bark.		54.8	0.000448	2.55
			30	54.6	0.00045	2.55
126........	7	Boise, Main	2	470	0.000334	3.81
		Sec. No. 3,		470	0.000246	3.48
		U. S. R. S.		238	0.0003	2.67
				238	0.000204	2.35
126........	8	Boise, Main		316	0.0003	3.08
		Sec. No. 2,	3	1 027	0.000288	4.68
		U. S. R. S.		476	0.000362	3.57
				245	0.000288	2.64
				119	0.000288	1.84
				1 209	0.000312	4.91

* References: 194 for *Bulletin No. 194*, U. S. Dept. Agri.
126 for *Bulletin No. 126*, U. S. Dept. Agri.
Colo. for *Bulletin No. 194*, Colo. Agri. Coll. Exp. Sta.

could be taken as the true value for the exponent of V. The writer found this to be 1.84, and the resulting expression is then:

$$S = A\ V^{1.84} \qquad (3)$$

This checks very closely that recommended by a number of authors for closed channels or pipes, giving the exponent of S in the first form of Equation (1) as 0.54.

Analysis for values for the term, A, was then taken up graphically. These values were then used with corresponding values of R, that is, R for the canal from which Equation (a) was determined, in a logarithmic plotting to ascertain the exponent of R. The data used necessarily had to be such as consisted of two or more measurements at different

THE VALUE OF THE EXPONENT OF R.

Mr. Sleight.

Hydraulic radius, R.	A, in $A = k\ R^p$.	p in $A = k_1\ R^p$.	C_1 in $V = C_1\ R^{0.88}\ S^{0.54}$.	Mean C_1.	Maximum percentage of variation from mean C_1.
1.90	0.0000837		89		
1.62	0.00001046		92		
0.91	0.000275	— 1.65	91	91	2.2
1.94	0.0000719		97		
1.63	0.0000912		97		
0.88	0.000242	— 1.58	101	98	3.1
0.51	0.000448		115		
0.38	0.00083		109		
1.41	0.0000866	— 1.68	114	113	3.5
0.49	0.000271		166		
0.67	0.0001426		172		
0.81	0.0001474		145		
0.76	0.0001015		171		
0.86	0.0001236	— 1.68	150	161	9.9
1.30	0.0000625		130		
2.13	0.0000319		137		
2.73	0.0000238		121		
3.29	0.0000174		126		
2.06	0.0000324		140		
3.24	0.0000174		134		
3.11	0.0000206		127		
2.90	0.0000230	— 1.39	127	130	7.6
1.71	0.0000495		134		
1.25	0.0000807		135		
1.25	0.0000801		135		
1.25	0.0000804	— 1.58	135	135	0.7
2.45	0.0000284		133		
2.65	0.0000248		131		
1.87	0.0000492		123		
2.09	0.0000423	— 1.91	121	127	4.7
2.14	0.0000378		125		
3.88	0.0000167		119		
2.64	0.0000348		109		
1.95	0.0000450		120		
1.44	0.0000940		109		
4.22	0.0000167	— 1.56	109	115	8.7

† Not all measurements on same reach; slopes taken from diagrams of Kutter's n.

stages of the same ditch. The correct formula would show the same frictional coefficient for the ditch lining, whether the ditch were flowing full or with only a small percentage of its capacity. The writer has found available only eight such experiments. These, with their numbers, references, etc., are given in Table 8. Fig. 9 shows the logarithmic diagram. The slopes of the lines vary somewhat, showing quite a range in the exponent of R. Again the arithmetical mean was taken, this average giving $R^{-1.63}$, and Equation (b) became

$$A = k\ R^{-1.63} \qquad (4)$$

Substituting this value of A in Equation (3), there results

$$S = k\ R^{-1.63}\ V^{1.84} \qquad (5)$$

which reduces to

$$V = C_1\ R^{0.88}\ S^{0.54} \qquad (6)$$

Mr. Sleight. The low extreme of the variation of the exponent of R is 0.76, the high extreme is 1.04. The low one is greater than shown in formulas of a similar type that have been recommended. At present, however, the writer can find no justification for making an average exponent lower than 0.88. The variation from the mean is large. All the measurements seem to have been made with care. The value of 0.54 for the exponent of S, when used in ascertaining the exponent of R, gave lines of a more nearly constant slope than could be obtained when any other value was used. Therefore, in adopting the values, $R^{0.88}\ S^{0.54}$, the writer believes them to fit the conditions investigated —and conditions quite generally for concrete-lined canals—more closely than other exponential expressions; but he does not claim that the exponential expression will represent exactly the flow in open channels.

Equation (6) gives a comparatively constant C_1 for ditches of apparently the same character. Throughout the range of data, the following values to be used with this formula are recommended:

For the best workmanship and alignment.........165
For use as an average...........................130
For very rough concrete, bad workmanship, or undesirable conditions generally.................. 70 to 90

Direct comparison can be made between the author's results and those given in this discussion in the case of Curve 1, or Experiments Nos. 46, 48, and 50. In this set the writer has a maximum variation in the values of C_1 of 3.4%, based on the lowest. The author has a maximum variation of computed velocity from the actual (which is equivalent to the variation in C_1) of 17.6 per cent. Possibly this comparison can hardly be called just, because the author's formula,

$$V = 80.3\ R^{0.69}\ S^{0.5},$$

does not fit any one of the three experiments nearer than 4.64%, as in Experiment No. 46.

For Curve 2, Experiments Nos. 45, 47, and 49, the author's formula fits more closely in the case of No. 47, where the variation is 1.05%, and it ranges to 6.2% in Experiment No. 49. The writer's maximum variation is 4.1%, on the basis of C_1.

Examination of Experiments Nos. 32, 33, and 34, again on the same canal, show that the author has a maximum variation from the actual velocity of 4.5%, calculated by his formula. The variation by the method discussed herein is 5.2%; but it will be noticed that the author's formula fits within 0.3% in the case of Experiment No. 33, or, for practical purposes, almost exactly; it runs too low, however, in computing Experiment No. 32, and too high for Experiment No. 34. These three measurements are on the same ditch. The formula does not apply to this channel.

Mr. Sleight.

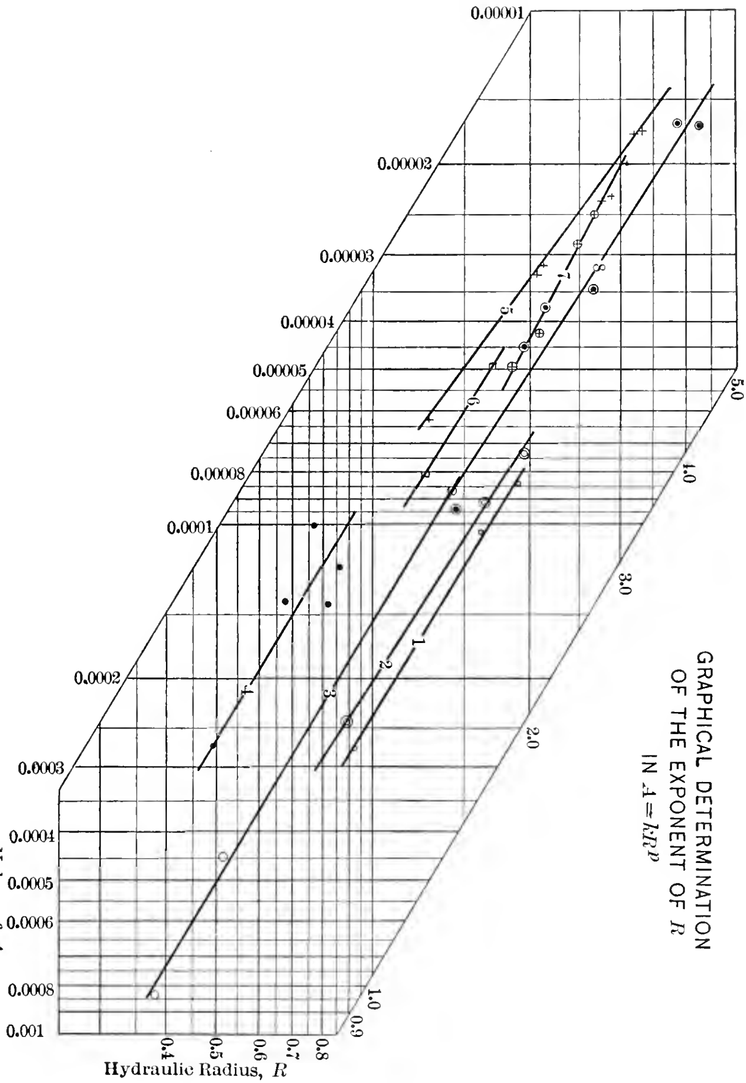

FIG. 9.

Mr. Sleight.

Experiment No. 15 the writer checks exactly by the use of the mean C_1 as found for all the measurements on this ditch. The author's variation is less than 1.0 per cent. The actual conditions of Experiment No. 30 are also checked exactly by the expression derived in this discussion; the author's variation is 2.7 per cent. In Experiment No. 2 the variation by the author's formula is about 1.0%, as compared with 4.5% by the formula described herein. Finally, taking Experiment No. 3, the author has a variation of 5.4% and the writer 3.4 per cent.

The last four comparisons cannot be given quite as much weight as those where more than one measurement on the same canal was available. On the whole, the data for comparison are not as complete as desired; still, it seems evident that

$$V = C_1 R^{0.88} S^{0.54}$$

is nearer the correct expression than

$$V = C R^{0.69} S^{0.5}.$$

It is unfortunate that more experiments are not available on the same reach of canal, with different depths of water. Although *Bulletin No. 194* by Mr. Scobey, and such investigations as that of the author, give all the information needed on which to base canal design, they do not present the necessary data to prove that the exponential formula of the type

$$V = C_1 R^m S^n$$

will apply exactly to the flow of water in open channels.

The writer at present believes that the exponential or logarithmic expression, unmodified, will not express exactly the velocity of flow in open channels when constant exponents are attempted for all types of such channels.

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PAPERS AND DISCUSSIONS

CONCRETE-LINED OIL-STORAGE RESERVOIRS IN CALIFORNIA: CONSTRUCTION METHODS AND COST DATA

Discussion.*

By E. D. Cole, Assoc. M. Am. Soc. C. E.†

E. D. Cole,‡ Assoc. M. Am. Soc. C. E. (by letter).—The writer must admit that Mr. Bowie is right in his contention that a wooden roof covered with ordinary roofing paper is rather poor construction when one considers the pains taken with the earthwork and concrete lining to make the reservoir oil-tight. However, as reservoirs of this type are intended at present only for storing fuel oil, and not the lighter grades which are used for refining purposes, the actual value of the oil lost by evaporation would be simply its market value as fuel. The writer believes that the lighter grades of oil can be stored successfully in concrete reservoirs, and that, eventually, this will be done, on account of the more economic type of construction. Then the roof specifications will no doubt be changed to include a covering which will be practically gas-tight. Mr. Cole.

* Discussion of the paper by E. D. Cole, Assoc. M. Am. Soc. C. E., continued from February, 1916, *Proceedings*.

† Author's closure.

‡ Santa Ana, Cal.

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PAPERS AND DISCUSSIONS

A STUDY OF THE DEPTH OF ANNUAL EVAPORATION FROM LAKE CONCHOS, MEXICO

Discussion.*

By Messrs. C. E. Grunsky and H. A. Whitney.

C. E. Grunsky,† M. Am. Soc. C. E. (by letter).—The writer desires to express his appreciation of the attempt made by the authors of this paper to establish the relation between mean monthly temperature and the evaporation from an open water area. He, too, has had occasion to study this problem, and believes that if a dependable relation can be pointed out it will prove of no small service to the engineer. Mr. Grunsky.

While Assistant State Engineer of California, the writer was placed in charge of evaporation studies at Kingsburg, Cal., the results of which have been published.‡ The writer also made use of these studies in a discussion of evaporation from the Salton Sea which he published§ in 1908.

In 1906, together with Dr. G. K. Gilbert and Professor F. H. Bigelow, he was a member of a Conference Board charged with outlining a programme for the evaporation work subsequently carried out at the Salton Sea and at Reno by the U. S. Weather Bureau under the supervision of Professor Bigelow.

The writer urged Professor Bigelow to devote some time and attention to the evaporation problem from the standpoint of the engineer, in order that a fairly reliable foundation might be laid for determining from known weather conditions, temperature, humidity, wind movement, and rainfall, with due regard to altitudes and loca-

* Discussion of the paper by Edwin Duryea, Jr., M. Am. Soc. C. E., and H. L. Haehl, Assoc. M. Am. Soc. C. E., continued from March, 1916, *Proceedings*.

† San Francisco, Cal.

‡ "Physical Data and Statistics", William Hammond Hall, M. Am. Soc. C. E., State Engineer of California, 1886, p. 379; and again published by the writer in *Bulletin No. 100,* U. S. Dept. of Agriculture, p. 323.

§ *Engineering News,* Vol. 60, August 13th, 1908, pp. 163–166.

Mr. Grunsky. tion, the monthly and annual evaporation rate. The published results of Professor Bigelow's observations will bear witness to the fact that the writer's appeal was of no effect, and that the engineer cannot get from those results the required basis for making, from weather conditions alone, a fair approximation of evaporation.

Messrs. Duryea and Haehl assume that Professor Bigelow used square pans in the evaporation work done by him at Salton Sea. In reading the papers by Professor Bigelow,* the writer could find nothing to indicate that the pans used there and elsewhere in his evaporation studies were square. The photographs of the work at Reno show that circular pans were used there, and the description thereof confirms this. Professor Bigelow, in describing the pans used at Reno,† refers to them as circular, 2 and 6 ft. in diameter and 10 in. deep. He says, further, that the depth of water in the pans was measured by a glass tube,

"graduated to cubic centimeters, the scale being nearly in millimeters, and the tube being drawn to a narrow neck at the bottom. A plunger consisting of a plug on a copper wire was fitted to move up and down with the finger as desired, * * *. Raising this to the level of the eye the top of the meniscus of water was easily read off to a fraction of a millimeter on the vertical scale. No account was taken of the volume, but the scale was read from time to time at the same point in each pan, and the difference of height between reading measured the amount lost by the evaporation."

In the last paper by Professor Bigelow,‡ he refers to the "diameter" of the pans which he used. He would not have made the mistake of referring to a diameter in describing a square pan. The pans at the Salton Sea, as well as at Reno, were circular. Professor Bigelow says:

"In order to test the ratio of evaporation from pans of different sizes, our records include the following combinations: (1) A 4-foot pan self-registered hourly and a 2-foot pan alongside on the ground near Tower No. 1; (2) a row of 3 pans, 2-foot, 4-foot, 6-foot in diameter, on a platform on Tower No. 3, about half a mile from shore, and as near the water as was practicable; (3) a row of 4 pans, 2-foot, 4-foot, 6-foot, 12-foot, on a series of adjoining rafts floating in the Salt Creek Slue in calm water. The ratios are quite steady and the results have been incorporated into the final value of the coefficient, $C_2 = 0.023\ (1.23)^n$ for 4 hour intervals,

where $n = 0$ for large open water areas,
$n = 1$ for 6-foot pans,
$n = 2$ for 4-foot pans,
$n = 3$ for 2-foot pans,
$n = 4$ for ordinary dry air.

* *Monthly Weather Review*, 1908 and 1910.

† *Ibid*, February, 1908.

‡ *Ibid*, July, 1910, pp. 1133–35.

The value of the coefficient for $n = 1$ is fairly well determined, and it is interpolated for $n = 4$. These should be further verified if possible." Mr. Grunsky.

It will be noted that the pans were circular, and that those at the water surface were not "floating", in the ordinary sense of the term.

On inquiry at the U. S. Weather Bureau, it has been learned from Mr. B. C. Kadel, who was in actual charge of the field work under Professor Bigelow, that the pans used were round (as will be seen from the reproduction of the photograph, Fig. 27) and that the rafts were arranged in line off shore with a dummy raft next to the shore. The pans were supported so that they were partly immersed in water

"but the water inside the pans was kept at a higher level than the water outside in order that the pressure would always be in the same direction. The 12-ft. pan was so large that it was almost impossible to buoy it much higher than the water in the bay."

In reference to the same pans, Mr. Bernard R. Laskowski, of the U. S. Weather Bureau at Denver, who assisted in the work, says: "The pans that were on rafts were balanced so that they rested about 3 or 4 in. in the water."

The results, relating to ratios of evaporation rates from various-sized pans, which were determined by Professor Bigelow, apply to land pans on platforms and pans generally with water surface above that of any surrounding water, and not to floating pans or those embedded in the soil. Furthermore, these comparisons apply to a factor in a formula, and not to the actual evaporation, and are therefore only approximations to the ratios of actual evaporation.

It may be added that the principal cause of the varying rates of evaporation from pans of different diameters is probably the acceleration of evaporation by capillary action at the sides of the pans. Under the cloudless sky of the Salton Sea region, where the Bigelow experiments were made, the metal rims of the pans above the water became very hot, with undoubtedly an appreciable effect on evaporation. The ratio of perimeter to area increases as the area of the water surface in the pans increases. This suggests that, perhaps, for all practical purposes, the formula for the Bigelow coefficient might be written

$$C_2 = 0.023 + 0.010\, c\, \frac{p}{a},$$

where p is the wetted perimeter of the pan, a is the area of the pan, and c is a coefficient to be determined for various materials of which pans are constructed; for various climatic conditions; and for the position and possibly, too, the depth of the pan. The coefficients determined for pans placed on platforms or freely swinging, as at Salton Sea, or for pans partly immersed, should not be applied to those embedded in the soil, nor to those floating in the water (with water at

Mr. Grunsky. the same level as the surrounding water), the sides of which are cooled in large measure from the outside, and not entirely by the evaporation of the water film attracted by capillary force on the inside.

For 10-in. deep land pans not embedded in the soil, in a climate comparable with that at Salton Sea, the value of c is unity, and the formula may be written

$$C_2 = 0.023 + 0.010 \frac{p}{a}.$$

This would make, for land pans in a Salton Sea climate:

$C_2 = 0.043$ for pans 2 ft. in diameter,
$C_2 = 0.036$ " " 3 " " "
$C_2 = 0.033$ " " 4 " " "
$C_2 = 0.030$ " " 6 " " "
$C_2 = 0.023$ for large water areas.

These values are in fairly close agreement with those recommended by Professor Bigelow.

Further observation, it is confidently expected, will show that, for floating pans, the value of c is small, and that the size of the pan has much less effect on the evaporation rate than observed from pans above the water at Salton Sea.

It is unfortunate that the Bigelow studies were restricted to the determination of the law of evaporation. He could not be made to see the importance of determining the relation between evaporation and the mean monthly temperature and the other ordinary and generally readily ascertainable weather conditions, such as wind movement and relative humidity. On this subject the writer took occasion to communicate with Professor Bigelow, both before and after he made his first tentative suggestion of a formula,* but without success. His attention was called to the fact that the mean water surface temperature of any inland lake or reservoir will bear some more or less definite relation to the mean temperature of the air, if this mean temperature is determined for sufficiently long periods, as, for example, a month. It is possible that periods of 10 or 20 days would have an advantage over a 30-day basic period, but the convenience of using the month as the time unit, owing to the availability of climatic records arranged by months, is too apparent to need discussion. The writer brought to Professor Bigelow's notice an article in which the preponderating influence of temperature on evaporation had been pointed out and in which the use of mean monthly temperatures as a guide in approximating the evaporation from a water surface such as that at Salton Sea was illustrated. This article† was prepared by the writer

* *Monthly Weather Review*, February, 1908.

† *Engineering News*, Vol. 60, August 13th, 1908, p. 163.

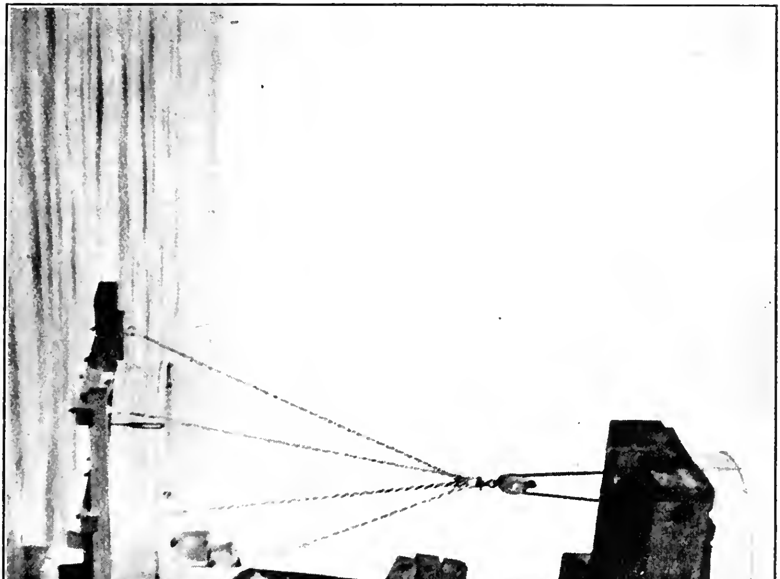

FIG. 27.—TOWER NO. 2, PANS 1 AND 2, SALTON SEA EVAPORATION CAMPAIGN.

in order to show that, throughout regions in which climatic conditions are similar, it may be assumed that errors due to more or less wind movement in one locality when compared with another, and those due to small differences in relative humidity and other similar causes, may be neglected, and, for all preliminary engineering purposes, evaporation from an open water surface may be determined from mean monthly temperature. Mr. Grunsky.

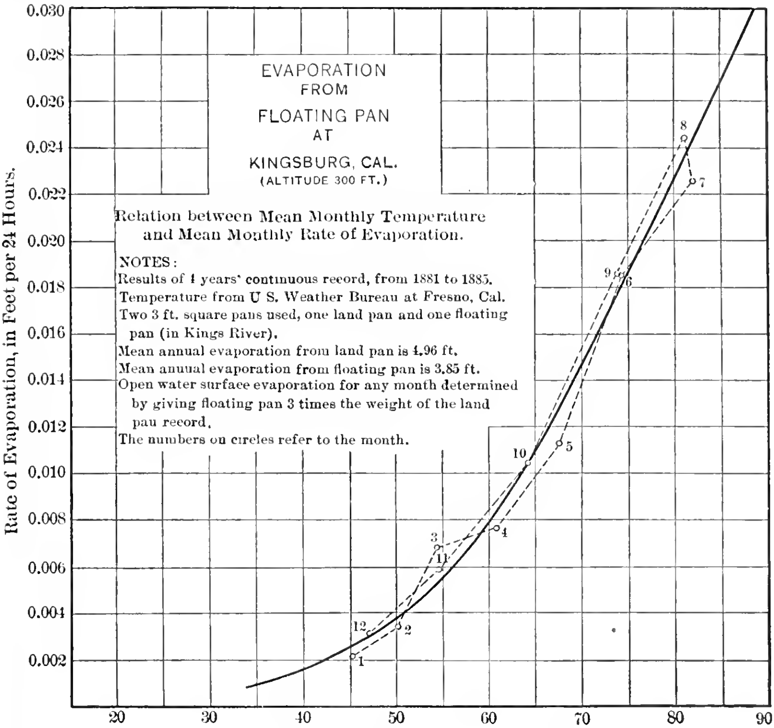

FIG. 28.

It will be apparent, however, that this can only be done after the relation between the mean monthly temperature and the rate of evaporation at one or more selected points during the calendar months has been determined experimentally. In the article referred to, the evaporation observations made at Lee Bridge, near London, during the 14 years, 1860-1873, by Mr. Charles Greaves,* the 6-year studies by Desmond FitzGerald, Past-President, Am. Soc. C. E., 1876 to 1886,†

* *Minutes of Proceedings*, Inst. C. E., Vol. XLV, 1875–76, p. 19.

† *Transactions*, Am. Soc. C. E., Vol. XV, 1886, p. 581.

Mr. Grunsky. at the Chestnut Hill Reservoir, Boston, and the 4-year records by the writer* under direction of William Hammond Hall, M. Am. Soc. C. E., State Engineer of California, at Kingsburg, Cal., are noted, and the relation between evaporation and the mean monthly temperature, as approximated from the Kingsburg record, is indicated.

At Kingsburg 3-ft. square pans were used, one on land and one floating in Kings River. During the first year the land pan was on a railroad trestle, thereafter on the land with earth banked around it to above the water surface. The pans were about 15 in. deep, and the depth of the water in the pans was about 10 in.

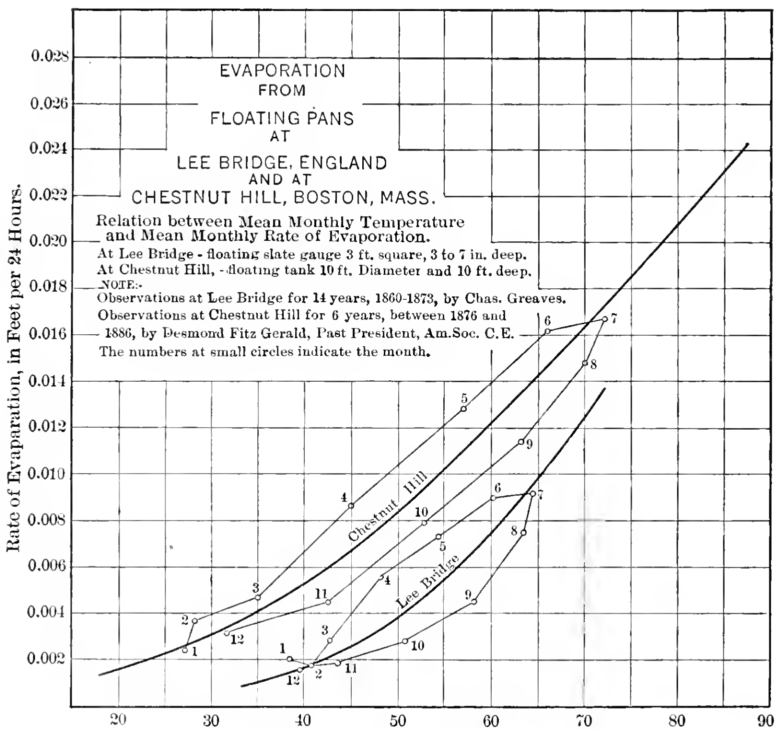

FIG. 29.

The observer was instructed to replenish the water in the pans by the use of a cup whenever it was found to be about ¼ in. below the top of a pointed peg in the center of the pan. The cup used was dimensioned to represent 0.01 ft. in depth. No attempt was made to establish the daily rate of evaporation.

* "Physical Data and Statistics", William Hammond Hall, M. Am. Soc. C. E., State Engineer of California, 1886.

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The results of the Kingsburg studies are summarized in Table 68 and the curve therefrom is shown in Fig. 28. The 4-year record showed 3.85 ft. as the average annual depth of water evaporating from the pan floating in the river, and 4.96 ft. as that from the pan on the ground.

The results of the observations at Lee Bridge and at Boston are as shown in Table 69 and Fig. 29.

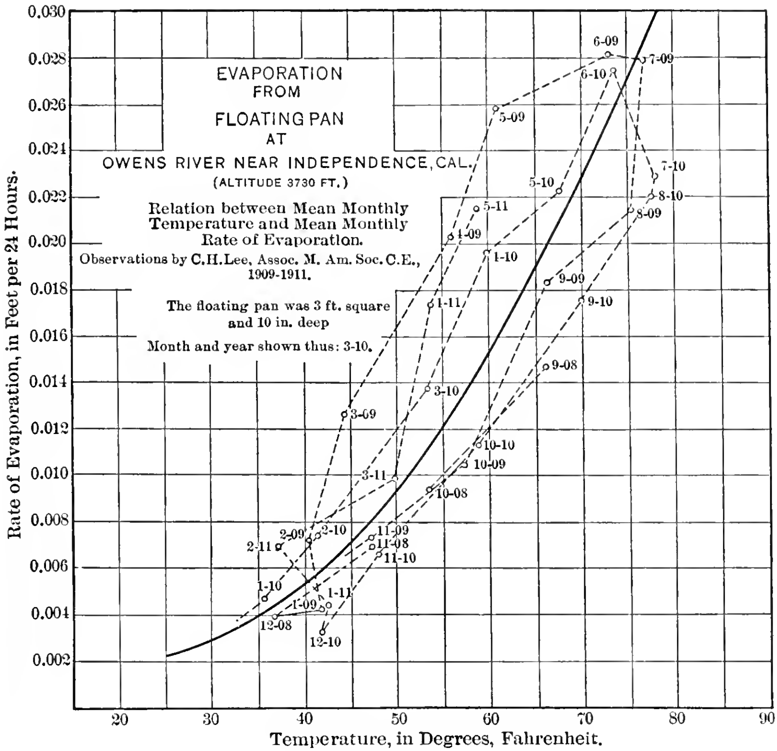

FIG. 30.

For comparison, the results of evaporation observations by Charles H. Lee, Assoc. M. Am. Soc. C. E., in Owens Valley, California, made for the Department of Public Works, Bureau of the Los Angeles Aqueduct, Los Angeles, in co-operation with the U. S. Geological Survey and the State of California, may also be referred to. These results have been published,* and have been used as the basis for Fig. 30, in which they will be found comparable with other studies of the relation betwen temperature and evaporation.

* *Water Supply and Irrigation Paper No. 294.*

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The Owens Valley pan was 3 ft. square and 10 in. deep; it was floating for a time in the water of Blackrock Slough and later in Owens River at the Citrus Bridge, about 4 miles east of Independence.

"The depth of water beneath the pan varied from 1 to 5 ft., depending on the river stage. The river had a moderate velocity and varied in temperature from about 75° Fahr. in summer to about 40° Fahr. in winter."

Mr. Lee says that in an embedded land pan, about 3 miles east of Independence, the water temperature ranged from 95° in summer to 32° in winter, and that a comparison month by month shows the excess of evaporation loss from the land pan to have been about 33 per cent. Stated in the usual way, the rate of evaporation from the floating pan was about 75% of that from the land pan.

TABLE 68.—EVAPORATION AT KINGSBURG, CAL., NOVEMBER, 1881, TO OCTOBER, 1885.

Temperatures are based on U. S. Weather Bureau records at Fresno from 1888 to 1902. The climate at Fresno is practically the same as at Kingsburg, which lies in the same great valley, 20 miles to the southeast.

Month.	Temperature, in degrees Fahrenheit.	EVAPORATION IN 24 HOURS, IN FEET.		
		Floating pan.	Land pan.	Open water (probable).
Jan	45.3	0.0021	0.0026	0.0022
Feb	50.2	0.0036	0.0033	0.0035
Mar	54.4	0.0066	0.0073	0.0068
Apr	60.8	0.0071	0.0095	0.0077
May	67.4	0.0091	0.0178	0.0133
June	74.1	0.0161	0.0259	0.0185
July	82.1	0.0203	0.0292	0.0225
Aug	81.0	0.0233	0.0278	0.0244
Sept	73.8	0.0180	0.0205	0.0186
Oct	64.2	0.0109	0.0093	0.0105
Nov	54.6	0.0059	0.0058	0.0059
Dec	47.0	0.0032	0.0034	0.0032

It was not the purpose of the Kingsburg observations to establish a law of evaporation, but to ascertain the probable annual evaporation from an open water surface. It is believed that the evaporation measured from the pan floating in Kings River was somewhat less than would have been observed from a pan floating on an open water surface, and less, too, than that from a large open water surface, for the reason that some protection against sun and wind was afforded to this pan by high river banks, a fringe of low trees, and a near-by bridge, and for the further reason that the temperature of the river was probably a little less than that which would have obtained in

TABLE 69.—EVAPORATION RECORDS AT LEE BRIDGE, ENGLAND, 1860-1873; AND AT CHESTNUT HILL, BOSTON, FOR 6 YEARS, BETWEEN 1876 AND 1886. Mr. Grunsky.

Month.	At Chestnut Hill.		At Lee Bridge.	
	Temperature, in degrees Fahrenheit.	Evaporation per 24 hours, in feet.	Temperature,* in degrees Fahrenheit.	Evaporation per 24 hours, in feet.
Jan	27	0.0026	38.5	0.0021
Feb	28	0.0030	40.8	0.0018
Mar	35	0.0039	42.5	0.0029
Apr	45	0.0066	48.1	0.0058
May	57	0.0103	54.2	0.0074
June	66	0.0148	60.2	0.0087
July	72	0.0167	64.0	0.0093
Aug	70	0.0161	63.3	0.0078
Sept	63	0.0135	58.4	0.0045
Oct	53	0.0093	50.6	0.0028
Nov	42	0.0062	43.9	0.0020
Dec	32	0.0037	39.5	0.0017

* The temperature for Boston is from U. S. Weather Bureau records for the period, 1873 to 1903, and the rate of evaporation is from FitzGerald's smoothed out curve.

an open body of water. The land pan, on the other hand, undoubtedly lost more water than would have been lost from the surface of a large open water body.

This reasoning led the writer to adopt values determined by giving the floating pan records three times the weight of those of the land pan as a basis for approximating evaporation rates from large bodies of water when mean monthly temperatures in their vicinity are known. He found it convenient to express the results in a diagram which he believes to be fairly dependable under the climatic conditions of the West and Southwest. The writer has some doubt, however (which he would like to see cleared up), concerning the rates indicated by the Kingsburg records at low temperatures. From very cursory comparisons with other records, it seems possible that the values indicated by the Kingsburg diagram at low temperatures are too low. Although such error, if it exists, will be apparent in the evaporation during the winter, it will not greatly affect the annual result, because the proportional evaporation in the winter is small.

It will be noted that the Kingsburg records indicate that the mean annual rate of evaporation from the pan floating in the river is about 78% of that from an embedded land pan, and that the ratio which the writer has accepted as probable between the 3-ft. square land pan at Kingsburg and an open water surface is about 83%, applicable to annual, but not to individual monthly, records.

The relation between the mean monthly temperature and the mean monthly rate of evaporation deduced from the Kingsburg record is as shown in Table 70.

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TABLE 70.—RELATION BETWEEN MEAN MONTHLY TEMPERATURE AND MEAN MONTHLY RATE OF EVAPORATION, BASED ON THE KINGSBURG RECORD.

Mean monthly temperature, in degrees Fahrenheit.	Evaporation from Open Water Surface. Mean Monthly Rate Per 24 Hours.	
	Feet.	Inches.
35	0.0010	0.012
40	0.0016	0.019
45	0.0025	0.030
50	0.0038	0.046
55	0.0055	0.066
60	0.0080	0.096
65	0.0110	0.132
70	0.0147	0.177
75	0.0187	0.225
80	0.0228	0.274
85	0.0270	0.324
90	0.0312	0.374

Although the fact is recognized that the rate of evaporation from a floating pan is not necessarily the same as that from the body of water which surrounds the pan, it is believed that, generally, there will be no great departure, and that lack of perfect agreement must be ascribed primarily to differences in water temperature which are ordinarily not large, but which, nevertheless, may cause some variation in the rate of evaporation from the pan and from the surrounding open water. In regions of much sunshine, it is believed that the pan should show a somewhat higher mean annual rate than the open water. It is probable, too, that the sides of the pan—due to capillary action—have the effect of accelerating evaporation, and that this is a contributary cause to the supposed excess of the pan rate over that of the open water. There is another reason, however, why a pan record of evaporation may not correctly represent the evaporation from a large water surface. This is found in the varying exposure to sun and wind of different portions of the water body. Departures due to this cause may be in either direction.

Although this is true, there is no evidence at hand, as already stated, to show that the same ratios will obtain between the evaporation rates from various sized pans floating in the water as apply to similar pans placed on the ground, or above the water surface, and not under temperature control by a large body of water.

The writer does not propose to examine the original data used by Professor Bigelow in determining the results relating to the effect of the size of the pan on the coefficient in the Bigelow evaporation formula, and does not question their reliability, but he desires to point out that the evaporation, according to the formula in which C_2 is a coefficient, is dependent on the water temperature and tempera-

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ture changes, and that, therefore, the formula cannot be used to show the relation between the evaporation from an open water surface and that from a floating pan, unless water temperature records are available. The writer believes that any conclusion, such as the authors deduce from the Bigelow results—that the evaporation from the open water surface of Lake Conchos was 62% of the evaporation from a 3-ft. square pan floating thereon—should be accepted with caution. This could only be the case if there was a material difference in temperature conditions between the surface water of the lake and the water in the floating pan, which is quite improbable.

Professor Bigelow had no pans floating on Salton Sea,* and therefore the relation between a floating-pan record and the annual evaporation, of about 6 ft., from Salton Sea, was not recorded by him. In view of the assumption now made by the authors—that the evaporation from a 3-ft. floating pan would be so much greater than that from a large open water surface—this is regrettable.

Conclusion (*a*), as stated on page 1733,† is probably correct if restricted to land pans (not embedded). They are based on Professor Bigelow's experiments with pans about 10 in. deep, with sides above the water, freely exposed to air and sun, and not cooled by surrounding water, and, for the present, they should be restricted to such pans.

For Conclusion (*c*) the writer can find no basis. By reference to page 1747† it will be seen that, because the coefficient in an evaporation formula based on water temperature and other factors varies from 0.023,‡ for open water, to about 0.039,‡ for a 3-ft. circular pan (not square), the authors have assumed this relation to apply to the annual evaporation rate. This latter relation was not established by Professor Bigelow's work.

Conclusion (*d*) on page 1733†—that the effect of a change in the mean monthly temperature is the same at low as at high mean monthly temperatures—should be weighed in comparison with such records as those at Chestnut Hill, Mass., at Lee Bridge, England, in Owens Valley, Cal., and at Kingsburg, Cal., all of which indicate a departure from this conclusion.

Although it may be admitted that, for the same mean monthly temperature, the evaporation is greater at high than at low altitudes, the law of this increase is not to be regarded as proven by the data presented in the paper, and Conclusion (*e*) on page 1733† should not be accepted without further verification.

In Table 17 the authors note floating pan evaporation for 14 stations, of which 11 are Piche evaporimeter calculations, as explained in

* Professor Bigelow says: "It was not possible to float pans in the waves of Salton Sea * * *". (*Engineering News*, Vol. 63, June 16th, 1910, p. 695.)

† *Proceedings*, Am. Soc. C. E., for September, 1915.

‡ *From Monthly Weather Review*, July, 1910, p. 1133, by F. H. Bigelow.

Mr. Grunsky. the table. Though it may happen that at some points the evaporimeter makes possible a close approximation of evaporation from a floating pan, it remains to be demonstrated that the record of the open air instrument may under all circumstances be substituted for, and called equivalent to, a floating-pan record. The conclusions reached by Professor Bigelow in reference to the effect of elevation above ground on the rate of the evaporation from small pans and the unknown position of the Piche instrument with reference to any possible water surface, should invalidate this substitution. Table 17, in the form in which presented, may be misleading, because the acceptance of an interchangeability of results as there made does not seem warranted. Nevertheless, the records in that table show for each station the close inter-relation between the mean monthly evaporation rate and the mean monthly temperature.

On page 1767* there is a reference to curves showing the relations between temperature and evaporation in "3-ft. square floating-pans at five measured evaporation stations on the Great Plateau." Of these stations, two—Albuquerque and Elephant Butte—had no floating pans, and at Carlsbad the record is a composite of an expanded floating-pan record at Lake Avalon and a land-pan record at Carlsbad. The latter is unreliable, and unquestionably indicates too small an annual evaporation rate. It seems to the writer that these records are of but little value in the discussion of the relation between evaporation from floating pans and temperature.

The results presented by the authors, in the diagram on Plate XXXIII, for all stations combined, should not be accepted as conclusive, for the reason, already pointed out, that the records on which the diagram is based are not all from floating pans, and for the further reason that the starting point in the matter of time has not been brought into any definite relation to the seasons. In the preparation of such a diagram, a uniform starting point in relation to the calendar year should be used. When this is done for such dependable evaporation records as those at Lee Bridge, England; at Chestnut Hill, Boston; and in Owens Valley, Cal., as also for the somewhat less dependable record at Kingsburg, Cal., it will be found that the curves will all have a pronounced ogee shape, their steepest inclination falling in the spring and summer months. This is due mainly to the fact, elsewhere noted, that at the lower temperature of the winter months the change in the evaporation rate due to each change of a degree in the mean monthly temperature is less than for the change of a degree in the warmer months of summer.

In Tables 38 and 39 the evaporation from pans on and at Lake Conchos is given. The land-pan records are used to deduce floating-

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* *Proceedings*, Am. Soc. C. E., for September, 1915.

pan records by applying a coefficient of 80% to the monthly records. It is probable that this factor fairly represents the relation between the yearly land-pan and the floating-pan evaporation rates, but it will hardly do to accept this as correct for the individual months. Mr. Grunsky.

In the winter, from December to February, inclusive, the floating pan will probably ordinarily show, as it does elsewhere, a rate of evaporation as great as, or greater than, that of the land pan, for the reason that the mean water temperature in cold months in the floating pan will be as high as, or higher than, that of the land pan. The probability is that the estimates which are based on Table 38 are too low, because in the 3 months, January to March, the evaporation from the land pan should be about the same as that from a near-by floating pan. Therefore, too much reliance should not be placed on the diagram, Fig. 15, showing the relation at Lake Conchos between the mean monthly temperature and evaporation from the lake's surface. The line there shown should probably be curved, indicating a smaller effect of temperature variation at low than at high temperatures.

The writer believes that the rate of evaporation in relation to mean monthly temperature increases with elevation in some measure, as shown by the authors on Table 17. It is reasonable to expect this, not only because the temperature at which water boils falls with increasing altitude, but, also, because the temperature range, particularly the diurnal range, ordinarily increases with altitude. According to the evaporation law, the mean monthly rate of evaporation will be greatest at that place which shows the greatest temperature fluctuations, because each degree of temperature above the mean produces more evaporation than each degree below the mean.

It is notable that the records for Lee Bridge, Chestnut Hill, and Owens Valley all indicate higher rates of evaporation for the spring months than for the fall months. Temperature is not the only controlling factor, and when mean monthly temperatures are used as the basis of an evaporation estimate, the results should be regarded as dependable for the entire year only, and not for the individual months, except possibly under similar climatic conditions. The Kingsburg record did not show the peculiarity of greater evaporation, for any given mean monthly temperature, in spring than in autumn.

On the assumption that the mean monthly temperatures are about as shown in Table 30, for 1913 and parts of 1912 and 1914, the Kingsburg curve indicates a mean annual evaporation from the water surface of Lake Conchos of 60 in. This is subject to correction for higher elevation. (Lake Conchos is at Elevation 4 300 and Kingsburg is about at Elevation 300.) This correction is perhaps but little in the hot summer months, but may affect the result materially in the

Mr. Grunsky. cold winter months. It is believed that this correction will not be as great as the curves presented in the paper would indicate, but, nevertheless, it may be an increase of from 20 to 30 per cent. It is the writer's opinion that further observations at Lake Conchos will show that the evaporation there will be between the 60 in. indicated by the Kingsburg curve and the 85 in. which the authors have estimated as the annual evaporation from a 3-ft. square pan floating on the water surface of the lake.

The results at Kingsburg, though not recommended as fully dependable, have been tested by the fall of the water surface at Salton Sea, where the check was satisfactory for the year 1907-1908.

If temperatures at Salton Sea for a normal year are approximated from the records at Indio by applying a probable correction, ascertained from the records at Mecca, nearer the Sea, and at Brawley, south of the Sea, they will be found to be about as shown in Table 71.

TABLE 71.—Evaporation from Salton Sea. Estimated from Mean Monthly Temperatures and the Kingsburg Evaporation Curve.

The temperatures at Indio were corrected by comparison with temperatures at Brawley and Mecca for temperatures at Salton Sea.

Month.	Mean monthly temperature, in degrees Fahrenheit.	Evaporation:	
		Foot per day.	Total, in feet.
Jan.	50.0	0.0038	0.118
Feb.	55.0	0.0055	0.154
March	62.5	0.0094	0.291
April	69.5	0.0144	0.432
May	77.0	0.0203	0.629
June	85.5	0.0274	0.822
July	91.5	0.0326	1.010
Aug.	90.0	0.0320	0.993
Sept	83.5	0.0261	0.783
Oct.	72.5	0.0167	0.518
Nov.	59.5	0.0076	0.228
Dec	53.5	0.0052	0.161
Total			6.239

Although it is probable that the temperatures as noted in Table 71 are somewhat too high when applied to the air above so large a body of water as the Salton Sea, they have been used to estimate—by the aid of the Kingsburg curve—the probable normal annual evaporation from Salton Sea. The evaporation from Salton Sea thus computed, and indicated in Table 71 for a normal year, is 6.24 ft., or 75 in.

This is about 12% in excess of the mean annual water loss from Salton Sea, as estimated by Mr. Robson for a 6-year period. Perhaps here, too, some correction should be applied for difference in elevation, Salton Sea being about 500 ft. lower than Kingsburg.

In conclusion the writer desires to repeat his statement of some years ago to Professor Bigelow, that no formula of the Dalton type, or of the type suggested by Professor Bigelow, will meet the requirements of the engineer when called on to determine from weather conditions alone the quantity of evaporation from a sheet of water not yet in existence. Mr. Grunsky.

H. A. Whitney,* M. Am. Soc. C. E. (by letter).—The Profession certainly is indebted to the authors of this paper for the thorough manner in which they have covered every detail. As the paper comes from engineers of high standing in the Profession, these studies are very valuable. Mr. Whitney.

The writer was Assistant Superintendent and Hydraulic Engineer of the Department of Water of San Diego, Cal., from 1912 to 1915, and is able to add materially to the evaporation data on the Upper Otay Reservoir in Table 57,† by Mr. Post.

From the beginning of February, 1913, until the close of December, 1915, continuous gauge readings of the water surface in the reservoir were taken, and these, with the corresponding rise and fall of the reservoir surface, rainfall on the reservoir, and net evaporation losses from it, are given in full in Table 72.

Similar gauge readings and rainfalls were taken at Chollas Heights Reservoir, for those months of 1914 and 1915 during which it is believed there was no inflow or outflow at that reservoir. The reservoir at Chollas Heights is used for reserve and for regulating the distributing system of San Diego. It is about 4 miles east of the eastern boundary of San Diego, and is fed from the 30-in. pipe leading from the Lower Otay Reservoir, which pipe conducts the run-off waters from the various drainage areas of the San Diego water system.

The Chollas Heights Reservoir is frequently drawn upon for reserve water, and a preliminary diagram of its gauge heights showed so many fluctuations of its surface in 1915, from accessions and uses, that only the 1914 records (when neither accessions nor uses were believed to have occurred) apparently were applicable to this discussion. Again, however, a tabulation of the 1914 Chollas Heights records similar to those in Table 72 showed monthly evaporation depths which, almost without exception, were so large as to be unreasonable or absurd; hence, the Chollas Heights gauge readings are dismissed from further consideration, as being unreliable data for evaporation. Merely as a surmise, it is supposed that at times water was withdrawn from that reservoir without the order or knowledge of the writer, or that the regulating valve was not entirely closed.

The rainfalls of Table 72 were measured in a standard 8-in. Weather Bureau rain gauge, near the Lower Otay Dam, about 3 miles down

* San Francisco, Cal.

† *Proceedings,* Am. Soc. C. E., for December, 1915.

Mr. Whitney.

TABLE 72.—Gauge-Readings of Surface, Rainfall, Etc., at Upper Otay Reservoir.

Date.	Gauge reading. (Distance of water below crest of dam.)		Rise (+) and fall (—) of reservoir surface, between dates of Column 1.	Correction for observed rainfall between dates of Column 1. (From Table 73.)	Algebraic sum of Columns 3 and 4; or probable evaporation from reservoir surface between dates of Column 1.	
(1)	(2)		(3)	(4)	(5)	
1913	Feet.	Inches.	Feet.	Feet.	Feet.	Inches.
Jan 1....	....	....				
			......	....	....	....
Feb. 1....	8	10				
			+ 2.17	*— 0.32	....	....
Mar. 1....	6	8				
			+ 0.42	— 0.06	....	....
Apr. 1....	6	3				
			+ 2.25	— 0.01	....	....
May 1....	4	0				
			— 0.42	— 0.00	— 0.42	= 5.0
June 1....	4	5				
			— 0.46	— 0.02	— 0.48	= 5.8
July 1....	4	10½				
			— 0.71	— 0.01	— 0.72	= 8.7
Aug. 1....	5	7				
			— 0.67	— 0.00	— 0.67	= 8.0
Sept. 1....	6	3				
			— 0.50	— 0.00	— 0.50	= 6.0
Oct. 1....	6	9				
			— 0.42	— 0.00	— 0.42	= 5.0
Nov. 1....	7	2				
			— 0.33	— 0.18	— 0.51	= 6.1
Dec. 1....	7	6				
			— 0.17	— 0.14	— 0.31	= 3.7
1914 Jan. 1....	7	8				
			— 0.08			
" 26....	7	9		— 0.25	....	....
			+ 0.50			
Feb. 1....	7	3				
			+ 0.50			
" 18....	6	9		— 0.18	....	....
			— 0.04			
Mar. 1....	6	9½				
			— 0.42			
Apr. 1....	7	2⅛		— 0.07	— 0.49	= 5.9
			— 0.50			
May 1....	7	8⅛		— 0.06	— 0.56	= 6.7
			— 0.44			
" 23....	8	1¾				
			— 0.15	— 0.01	— 0.60	= 7.2
			(— 0.59)			
June 1....	8	3½				
			— 0.12			
" 13....	8	5				
			— 0.21			
" 20....	8	7½		— 0.00	— 0.56	= 6.7
			— 0.13			
" 28....	8	9				
			— 0.10			
			(— 0.56)			
July 1....	8	10¼				
			— 0.23			
" 11....	9	1				
			— 0.17	— 0.00	— 0.73	= 8.8
" 18....	9	3				
			— 0.33			
			(— 0.73)			

* If rain had not occurred, the surface would have risen less or fallen more.

TABLE 72—(*Continued*).

Mr. Whitney.

Date.	Gauge reading. (Distance of water below crest of dam.)		Rise (+) and fall (—) of reservoir surface, between dates of Column 1.	Correction for observed rainfall between dates of Column 1. (From Table 73.)	Algebraic sum of Columns 3 and 4; or probable evaporation from reservoir surface between dates of Column 1.	
(1)	(2)		(3)	(4)	(5)	
1914	Feet.	Inches.	Feet.	Feet.	Feet.	Inches.
Aug. 1....	9	7				
			— 0.33			
" 15....	9	11				
			— 0.06	— 0.00	— 0.67 (*a*)	= 8.0
" 26....	9	11¾				
			— 0.27			
			(— 0.67)			
Sept. 1....	10	3				
			— 0.58	— 0.00	— 0.58 (*b*)	= 7.0
Oct. 1....	10	10				
			— 0.25			
" 16....	11	1		— 0.07	....	....
			† — 11.92			
Nov. 1....	23	0				
			— 0.08	— 0.05	— 0.13	= 1.6
Dec. 1....	23	1				
			— 0.92	— 0.21	— 1.13	= 13.6
1915						
Jan. 1....	24	0			...	....
			+ 7.75	— 0.36		
Feb. 1....	16	3				
			+ 7.50	— 0.33	....	....
Mar. 1....	8	9				
			+ 2.25	— 0.07	....	....
Apr. 1....	6	6				
			— 0.04			
" 15....	6	6½		— 0.15	....	....
			+ 0.12			
May 1....	6	5				
			— 0.08			
" 5....	6	6				
			— 0.08			
" 9....	6	7				
			— 0.09	— 0.08	— 0.66	= 7.9
" 14....	6	8				
			— 0.08			
" 18....	6	9				
			— 0.08			
May 22....	6	10				
			— 0.09			
" 26....	6	11		......	....	....
			— 0.08			
			(— 0.58)			
June 1....	7	0				
			— 0.08			
" 6....	7	1				
			— 0.09			
" 11....	7	2				
			— 0.08			
" 16....	7	3		— 0.00	— 0.50	= 6.0
			— 0.08			
" 21....	7	4				
			— 0.09			
" 26....	7	5				
			— 0.08			
			(— 0.50)			

† Withdrawal for water supply.

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TABLE 72—(*Continued*).

Date.	Gauge reading. (Distance of water below crest of dam.)		Rise (+) and fall (—) of reservoir surface, between dates of Column 1.	Correction for observed rainfall between dates of Column 1. (From Table 73.)	Algebraic sum of Columns 3 and 4; or probable evaporation from reservoir surface between dates of Column 1.	
(1)	(2)		(3)	(4)	(5)	
1915	Feet.	Inches.	Feet.	Feet.	Feet.	Inches.
July 1....	7	6				
			— 0.08			
" 5....	7	7				
			— 0.09			
" 9....	7	8				
			— 0.08			
" 13....	7	9				
			— 0.08			
" 17....	7	10		— 0.00	— 0.67	= 8.0
			— 0.09			
" 20....	7	11				
			— 0.08			
" 24....	8	0				
			— 0.08			
" 28...	8	1				
			— 0.09			
			(— 0.67)			
Aug. 1....	8	2				
			— 0.08			
" 5....	8	3				
			— 0.08			
" 9....	8	4				
			— 0.09			
" 13....	8	5				
			— 0.08			
" 17....	8	6		— 0.01	— 0.83	= 10.0
			— 0.09			
" 21....	8	7				
			— 0.08			
" 25....	8	8				
			— 0.09			
" 29....	8	9				
			— 0.25			
			(— 0.84)			
Sept. 1....	9	0				
			— 0.42	— 0.00	— 0.42	= 5.0
Oct. 1....	9	5				
			— 0.33	— 0.00	— 0.33	= 4.0
Nov. 1....	9	9				
			— 0.33	— 0.06	— 0.39	= 4.7
Dec. 1+...	10	1				
			+ 0.04	— 0.22	....	....
1916 Jan. 5....	10	0½	....	....	....	....

stream from the Upper Otay Reservoir. There was a similar rain gauge near the Chollas Heights Reservoir, nearly 12 miles from the Lower Otay rain gauge, and, for comparison, the monthly rainfalls by the two gauges are given in Table 73.

From the close agreement between both the monthly and seasonal rainfalls at the Lower Otay and Chollas Heights rain gauges (and from the rainfalls at Sweetwater Reservoir given in Table 57), it is evident that no material errors can be introduced by using the Lower Otay

TABLE 73.—RAINFALLS NEAR UPPER OTAY AND CHOLLAS HEIGHTS RESERVOIRS.

Mr. Whitney

Date.	Near Upper Otay Reservoir.		Near Chollas Heights Reservoir.	
	Depth, in inches.	Depth, in feet.	Depth, in inches.	Depth, in feet.
1913				
Jan.	1.51	0.13	No rain gauge readings taken.	
Feb.	3.89	0.32		
Mar.	0.67	0.06		
Apr.	0.15	0.01		
May	0.04	0.00		
June	0.23	0.02		
July	0.10	0.01		
Aug	0.05	0.00		
Sept	0.00	0.00		
Oct.	0.01	0.00		
Nov.	2.17	0.18		
Dec.	1.63	0.14		
	(10.45)	(0.87)		
1914				
Jan.	2.98	0.25	3.48	0.29
Feb.	2.17	0.18	2.51	0.21
Mar	0.85	0.07	0.61	0.05
Apr	0.78	0.06	1.05	0.09
May	0.15	0.01	0.04	0.00
June	0.00	0.00	0.16	0.01
July	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00
Sept	0.00	0.00	0.00	0.00
Oct	0.08	0.07	1.47	0.12
Nov	0.63	0.05	1.11	0.09
Dec.	2.58	0.21	3.22	0.27
	(10.94)	(0.90)	(13.69)	(1.13)
1915				
Jan.	4.28	0.36	5.34	0.45
Feb.	3.97	0.33	4.71	0.39
Mar	0.87	0.07	0.74	0.06
Apr	1.79	0.15	1.74	0.15
May	1.00	0.08	0.86	0.07
June	0.00	0.00	0.01	0.00
July	0.00	0.00	0.00	0.00
Aug	0.15	0.01	0.00	0.00
Sept	0.00	0.00	0.00	0.00
Oct	0.00	0.00	0.00	0.00
Nov	0.76	0.06	1.31	0.11
Dec.	2.68	0.22	1.19	0.10
	(15.50)	(1.28)	(16.00)	(1.33)

rainfalls in connection with the Upper Otay Reservoir, especially for the practically rainless months for which the evaporation depths are given in Table 72. The monthly evaporation depths of Table 72 are summarized and compared in Table 74.

The Upper Otay Reservoir is about 13 miles southeast of San Diego and about 550 ft. above the sea. It is approximately 1 mile long and ½ mile wide. At gauge height, 3 ft. below top of dam, it has an area of 160 acres and an average depth of 20.7 ft.; 10 ft. lower its area is 115 acres and its average depth 16.8 ft. It is essentially a storage reservoir, and both accessions to it and withdrawals from it are comparatively infrequent.

Mr. Whitney.

TABLE 74.—MONTHLY EVAPORATION DEPTHS, UPPER OTAY RESERVOIR, IN INCHES.

Month.	1913.	1914.	1915.	Mean.	Range.
March	....	5.9	....	(1) 5.9	....
April	....	6.7	....	(1) 6.7	....
May	5.0	7.2	7.9	(3) 6.7	(5.0 to 7.9)
June	5.8	6.7	6.0	(3) 6.2	(5.8 to 6.7)
July	8.7	8.8	8.0	(3) 8.5	(8.0 to 8.8)
August	8.0	8.0	8.0	(3) 8.0	(8.0 to 8.4)
September	6.0	7.0	5.0	(3) 6.0	(5.0 to 7.0)
October	5.0	5.0	4.0	(3) 4.7	(4.0 to 5.0)
November	6.1	....	4.7	(2) 5.4	(4.7 to 6.1)
December	3.7	....	....	(1) 3.7	(..........)
	48.3	55.3	43.6	(10) 61.8	

As a general rule (with recent very notable exceptions) the rainfalls near San Diego are infrequent and small, those of many of the months causing no run-offs or stream flows; and, during the months included in Table 74, the writer believes, from his knowledge of the local conditions, that there were no material accessions to the waters in the Upper Otay Reservoir except the small rainfalls on its surface, no material withdrawals for water-supply uses, no losses from visible seepage, and probably no material losses from absorption by the bottom of the reservoir and additions to the ground-water. There are about 3 acres of tules or cattails in the reservoir, which, by their transpiration, probably increase the evaporation losses slightly; but, because of their small proportionate area, their influence on the evaporation depth for the whole reservoir cannot be material.

Hence, it is believed that the evaporations of Table 74 may be accepted as fairly reliable values for the evaporation depths from the Upper Otay Reservoir for the months and years given.

From Table 56, showing the monthly percentages near San Diego of the total yearly evaporation, the total evaporation depths of Table 74 should be the following percentages of the total yearly depth:

1913—May-December, incl. 79%
1914—March-October, incl. 82%
1915—May-December, incl. 75%

Hence, from Table 74 and the percentages as taken from Table 56, the total yearly evaporation depths should be about as in Table 75.

The total yearly evaporations for the 3 years vary rather widely from each other, having an extreme variation of 9.3 in. Assuming the mean for the 3 years as 62.2 in., the evaporation depth for 1913 was 2% below the mean, that for 1914 was 8% above it, and that for 1915 was 6.7% below it.

From Table 56, the yearly evaporation depths from the Sweetwater Reservoir (5 miles from the Upper Otay Reservoir) for the 5 years,

Mr. Whitney.

TABLE 75.—PROBABLE NET EVAPORATION, IN INCHES, FOR 1913, 1914, AND 1915, FROM THE WATER SURFACE OF UPPER OTAY RESERVOIR.

Month.	1913.	1914.	1915.	Mean.	Percentage.
January	2.5*	2.7*	2.4*	2.5 +	4.0
February	3.0*	3.4*	2.9*	3.1	5.0
March	3.0*	5.9	2.9*	3.9 +	6.3
April	4.3*	6.7	4.1*	5.0 +	8.0
May	5.0	7.2	7.9	6.7	10.7
June	5.8	6.7	6.0	6.2 +	10.0
July	8.7	8.8	8.0	8.5	13.6
August	8.0	8.0	8.0	8.0	12.9
September	6.0	7.0	5.0	6.0	9.6
October	5.0	5.0*	4.0	4.7 +	7.6
November	6.1	3.4*	4.7	4.7 −	7.6
December	3.7	2.7*	2.3*	2.9	4.7
	61.1	67.5	58.2	62.2	100.0

* The evaporations for these months were calculated from the percentages shown in Table 56. The evaporation for October, 1914, is estimated from the 16th to the 31st.

1910 to 1914, varied from 45.76 to 63.32 in., with a mean of 56.98 in. So far as can be judged by the 3 years' observations there, the mean yearly evaporation depth from the Upper Otay Reservoir should be approximately 62.2 in. However, evaporations were measured from the water surfaces for 1913 and 1914 at both the Upper Otay and Sweetwater Reservoirs, with the following comparative results:

The evaporation from the Sweetwater Reservoir from April 30th to December 31st, 1913, was 45.23 in., and at the Upper Otay from April 30th to December 31st, 1913, it was 48.3 in., making the evaporation from the Sweetwater Reservoir 93½% of that from the Upper Otay.

From March 1st until October 31st, 1914, the evaporation from the surface of the Sweetwater Reservoir was 41.02 in., and that from the water surface of the Upper Otay Reservoir for the same period (from May 1st to October 31st, the last half month being approximated) was 55.3 in., thus making the evaporation from the water surface of the Sweetwater Reservoir 74.1% of that from the Upper Otay Reservoir.

As the two reservoirs are only 5 miles apart, and their evaporation conditions apparently do not differ materially, the wide variation in their evaporation depths for 1914 throws some doubt on the accuracy and reliability of the evaporation records of that year at one or both of the reservoirs. No account was taken of the gauge heights subsequent to letting out the water from the Upper Otay Reservoir on October 17th, 1914. As already mentioned, the evaporation of the last 2½ months of that year was estimated from the percentages given in Table 56.

On October 16th, 1915, daily readings were begun with a 3-ft. square evaporation pan floating on the Lower Otay Reservoir, and these measurements were continued until the Lower Otay Dam failed, on January 27th, 1916.

Mr. Whitney.

As shown by the notes, the replenishing water was measured daily only to the nearest quart, a quart equalling 0.04448 in. depth in the 3-ft. square pan. Of course, the even quart or quarts added each morning sometimes fell a little short of the top of the sharpened pin in the pan, and sometimes overran it slightly, and thus introduced more or less error into the daily evaporations; but it is evident that for a number of quarts, as for a month, the error thus introduced is negligible. The pan evaporations thus measured were as follows:

For all October, 1915 = 5.0 in. ($2\frac{1}{2}$ in. measured Oct. 16-31).
" " November, " = 3.3 " (8.3 in. cumulative).
" " December, " = 4.4 " (12.7 in. cumulative).

From Table 75, the evaporations from the reservoir during the same months were as follows:

For all October, = 4.0 in.
" " November, = 4.7 " (8.7 in. cumulative).
" " December, = 2.3 " (11.0 in. cumulative).

The comparisons of the evaporations from the reservoir with those from the pan are given in Table 76.

TABLE 76.—EVAPORATIONS FROM THE UPPER OTAY RESERVOIR, AS PERCENTAGES OF THE EVAPORATIONS FROM A 3-FT. SQUARE PAN FLOATING THEREON.

Monthly.				Cumulative.			
Month.	Reservoir.	Pan.	Percentage.	Period.	Reservoir.	Pan.	Percentage.
	Inches.	Inches.			Inches.	Inches.	
Oct........	4.0	5.0	80	Oct.	4.0	5.0	80
Nov........	4.7	3.3	142	Oct. and Nov.	8.7	8.3	105
Dec........	2.3	4.4	52	Oct., Nov., and Dec.	11.0	12.7	87

In reference to some of the other reservoirs mentioned by Mr. Post, the writer has a slight personal knowledge of the conditions at the Murray Hill Reservoir, and believes there is quite a little seepage from it, which (if corrected for) would make the evaporation from it somewhat less than the 1.60 in. shown on page 2699.*

In reference to the comparisons between the evaporations from the Cuyamaca Reservoir and from a floating pan in Table 58, it is believed that (because of the flatness of the land around the reservoir) comparatively large run-offs may be fed into it during rainy months by underwater springs and rock crevices, which accessions no run-off records can show.

* *Proceedings*, Am. Soc. C. E., for December, 1915.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

METHOD OF DESIGNING A RECTANGULAR REINFORCED CONCRETE FLAT SLAB, EACH SIDE OF WHICH RESTS ON EITHER RIGID OR YIELDING SUPPORTS

Discussion.*

By Edward Godfrey, M. Am. Soc. C. E.

Edward Godfrey,† M. Am. Soc. C. E. (by letter).—At the conclusion of Mr. Janni's abstruse mathematical paper he states that: Mr. Godfrey.

"* * * the calculation of the moments in a reinforced concrete floor system cannot be carried out with any 'ready made' set of formulas, but that each and every case is a problem by itself."

In solving a problem, Mr. Janni has found it necessary to go nearly to the mathematical limit, even using the principle of least work, which, being interpreted, means the greatest work for the practical designer to understand.

Perhaps not one practical designer in a hundred can follow the author's analysis. Those who can are generally teaching mathematics or are mathematical prodigies. Every author of a technical paper should recognize the fact that practical designers, as a class, especially designers of building work, have not the time nor the inclination—many of them have not the capacity—to follow intricate mathematical processes. For them, formulas must be pre-digested; and, after all, are not all such formulas really put into use—when they do find use—by every-day designers?

There are some instances of designing work where the higher mathematics and complex formulas are necessary, such as for suspen-

* This discussion (of the paper by A. C. Janni, M. Am. Soc. C. E., published in February, 1916, *Proceedings*, and presented at the meeting of April 5th, 1916), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† Pittsburgh, Pa.

Mr. Godfrey. sion and cantilever bridges, and, to some extent, draw-bridges; but these are somewhat rare, and are not touched by average designers. An attempt to introduce corresponding problems into ordinary building design is apt to result in the attempt reposing just where it originated—in the journal of an engineering society.

Mr. Janni might have solved this problem without the use of the principle of least work, for the benefit of those of the "old school" who were not taught on those lines. The writer, for one, has never had occasion to use it, as he has been able to solve such problems by simpler methods. Taking the author's expression for M in Equation (4), leaving out Fx, and using the familiar form,

$$\frac{d^2 y}{d x^2} = \frac{M}{E I},$$

the first integration gives the value of M_o identical with his, when equated to 0, with $x = \frac{l}{2}$; and the second integration gives the equation of the elastic line, from which the value of $E I D$ may readily be written. This value is identical with that by the author in Equation (10). The process is very much simpler, and more easily understood.

The writer believes that he was the first to use this method of treating a slab supported on four edges, namely, by taking the two strips across the middle of the rectangle and observing that the load on the middle square unit is divided between these two; also, that each strip carries an increasing load toward its supports, which may be assumed to vary as the ordinates of a parabola. He published this method for a square slab in 1907, and it was promptly inserted in a technical handbook,* without giving proper credit. In 1908 he applied the same method to an oblong slab freely supported on the edges. This was just in time for the Joint Committee, in its 1909 report, to use what the writer deduced, namely, when the sides of the oblong are as 2 to 3, the full load is taken in the short direction, but the Committee clung to this classical error:

$$r = \frac{l^4}{l^4 + b^4}.$$

This error will be referred to later.

Mr. Janni would have done better to ignore Poisson's ratio, which is purely theoretical, and has never had any practical demonstration in any tensile test. The writer has never found a single engineer who would apply Poisson's ratio in the case of a hollow sphere under internal pressure and reduce the thickness of the shell to less than that demanded by the ordinary strain. This is the ideal case where that

* "Principles of Reinforced Concrete Construction", by Edward R. Maurer and F. E. Turneaure.

ratio would apply, if it applies anywhere. This ratio is intended for a material of uniform strength and elasticity in all directions. It could not possibly apply to a combination of concrete and rods, the latter being in only two directions. The tests which appear, to some, to show the effect of Poisson's ratio show merely the effect of tensile strength in the concrete. Mr. Godfrey.

The writer does not see any necessity for the assumption that the supporting beams deflect and the resulting complexity introduced by it, especially in view of the very rough assumption near the top of page 209,* that the end moment is two-thirds of the fixed-ended condition. The writer does not follow all the process at the bottom of page 210;* too much is left to the imagination. It appears that the $A\ C$ portion of the beam has a uniform load. The reason for this is not evident, since this is also a middle strip in a rectangular slab. Furthermore, the value deduced, in the practical example, for M''_C near the bottom of page 211* is found by using inches as a unit throughout, though 552.8 ft-lb. is given as the result. If this is corrected to inch-pounds, it is seen to be too slight to need any consideration.

By leaving out of consideration the deflection of the supporting girders, the solution would be greatly simplified. The moment at the middle point of a critical strip will then lie somewhere between that found by the author (ignoring Poisson's ratio) for the fixed-ended condition and that found by the writer† for the free-ended condition. A far more potent factor which affects this moment is the unloaded condition of surrounding panels. In ordinary design, free-ended beams have the coefficient, $\frac{1}{8}$, in the bending moment; this is reduced to $\frac{1}{10}$ and $\frac{1}{12}$ for interior panels. Why could not similar reductions be allowed for flat slabs? This would take the problem out of the province of abstruse mathematics and place it where a building code could reach it.

Mr. Janni's solution is based on fixed-ended beam strips. This applies, not only to the moment, but to the value of α. To assume the beam strips only partly fixed-ended alters the value of α. Though this alteration is too small to need consideration, it is perhaps greater than the effect of deflection of the beams.

Mr. Janni finds that when the ratio of the two span lengths is as 3 to 5, the strip in the short direction will take all the load, that is, $k = 1$. The writer's solution, for freely supported edges, gives this value unity when the ratio is 2 to 3. The Joint Committee Report gives a formula which has already been referred to as a "classical error". This formula is based on assumed equal deflection of uni-

* *Proceedings*, Am. Soc. C. E., for February, 1916.

† "Concrete", 1908, p. 289.

Mr. Godfrey. formly loaded strips. The strips would have to be free to deflect as simple beams. Two or three minutes of thoughtful consideration ought to convince any one familiar with the principles of mechanics that the derivation of this formula is totally wrong; and yet it permeates the entire literature of reinforced concrete. It is in the Joint Committee Report, in "Standard Practice" issued by the American Concrete Institute, in practically all the building codes, and in nearly all the books by standard authors. This error was first propagated by European regulations, so that it is international. The writer pointed it out* and has repeatedly called attention to it.

This error is only one sample of how the literature of this subject was slapped together. Authors, code writers, and committees eagerly seized on anything, with no investigation whatever as to its correctness.

This is how the plain concrete column, the rodded column, the stirrup, the bunching of steel rods in the bottom of a beam—all of them absolutely dangerous—have become, and to a large extent remain, standards, to the everlasting shame of the men responsible and to the detriment of the best form of building construction ever devised.

A peculiarity about the Joint Committee Report and "Standard Practice" is that, coupled with this erroneous formula, the rule is given that when the sides of the rectangle are as 2 to 3, the full load is to be taken the short way, in spite of the formula which shows only 83% of it going in that direction. A little matter of an error of 20% does not seem to bother a set of men whose only answer to criticism was to repeat exactly the same indefensible errors four years later.

It takes about ten years for an error to be eradicated after it has once been espoused by the men who consider themselves authorities, no matter how clearly it is demonstrated. The writer hammered about that long on under pressure on dams before it began to be acknowledged to be the standard thing to do, namely, to design a dam to resist upward pressure. He has been hammering nearly that long on the rodded column and the stirrup, and the point has been reached where no engineer who reads English will dare to take up a public defense of either the stirrup or the rodded column.

The flat slab, supported on all edges on girders, does not find very many users. The flat slab supported on posts does find many users, and these users have set up a series of unscientific tests, which have been interpreted to suit themselves, and on which to base their standards of design. Then they have to call in Poisson's ratio, and invent such terms as bond-shear, and set up hypotheses as to new and strange properties of the combination of steel and concrete, all to hide the fact that tension in the concrete is performing the work that they

* *Engineering News*, June 3d, 1909.

would fain have engineers believe is being performed by the steel because of the "patented' way in which it is placed. Mr. Godfrey.

It is beginning now to be realized that there is a static limit below which the bending moment in a flat slab cannot possibly lie. The writer pointed this out,* in 1912, and has reiterated it at different times since then. Proponents of the flat slab, who can pass their hand over a bending moment and then show the audience that it is only half as great as before, and then repeat the trick on the same bending moment, no longer awe an audience of engineers. As the writer pointed out† in 1915, the concrete in a whole slab may be taking six times as much tension as the steel. These advocates of flat slabs attribute all this work to the steel because, forsooth, "tension in concrete is not to be relied upon permanently"—the very reason that all tension in the concrete should be accounted for and additional steel supplied to take it, for the sake of safety.

Tests ought to be made by the Federal Government, not by patent owners, interpreted by their hired experts. These tests ought to be on actual structures with columns only capable of sustaining one floor—not great first-story columns in a high building, or large piers sustaining a small slab, for the columns play a large part in flat slab tests; not spot loads in the middle of a wide expanse of floor; and not exterior panels supported by deep girders on walls. All these misleading features characterize the tests of record. No long row of panels completely across a building has been tested. No exterior line of panels without a deep girder or a wall has been tested.

The writer made the recommendation to the Director of the Bureau of Standards, in the presence of a number of concrete engineers, that the Bureau put up sample structures and test them to destruction. No high-cost testing machine, no matter how perfect, can ever discover what a rodded column will do in a building for, the more perfect the machine and the more ideal the test, the less the value of the results.

Tests where stress in the steel is measured have very little value, for the following reasons:

(*a*) The concrete is at the same time taking many times as much tension as the steel.

(*b*) The concrete may crack, and then all of this tension is in the steel.

(*c*) Measurements with a strain gauge, through the medium of two holes dug into the concrete to the steel, do not, in fact, tell the actual unit stress in the steel, but only the average unit stress in the measured length. If a crack occurs in this length, the unit stress may be very greatly increased for a very short length, but the effect in elongation of this is distributed over the full gauged length. This

* *Engineering News*, February 29th, 1912.

† In a paper before the American Concrete Institute in February, 1915.

Mr. Godfrey.

phase of the result of strain gauge measurements on embedded steel has received no attention.

Flat slab rules of design are being codified, and it behooves independent engineers to take up the question before patent owners mess it up, as they have done in the case of general design in reinforced concrete. Present standards, with their plain concrete columns, their rodded columns, their stirrups or short shear members, their rods bunched in the bottom of beams—every one wreck breeders—are an outrage and a disgrace. Engineers who are interested in sustaining the honor of the Profession should do all in their power to stem the tide of wrecks that has flowed in the last ten years, due to bad design—almost wholly standard design—by demanding safe design.

To this end the theory of flat slabs ought to be simplified, rather than the reverse. The simplest criterion is to consider a slab on rows of columns just as a slab would be considered on rows of beams. Commercial rules and the Chicago ruling will not meet this criterion, and no engineer has appeared to show why they should not.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

DISCUSSION ON FLOODS AND FLOOD PREVENTION*

By Messrs. M. O. Leighton, Cyrus C. Babb, Kenneth C. Grant, and B. F. Groat.

M. O. Leighton,† M. Am. Soc. C. E. (by letter).—The writer's impression, gained by reading this report, may be expressed substantially as follows: Here is a Committee of eminently qualified engineers—unquestionably as well qualified as could be selected from the Engineering Profession. To this Committee has been assigned one of the most important and difficult subjects in the engineering field. As the members of the Committee are eminent engineers, it follows naturally that they are very busy men. They realize, more acutely than any reader of their report can, that they have not had the time to give their subject the attention that it deserves. Having accepted appointment to this Committee, they do not wish to shirk the service involved. Therefore, they have made a safe and conservative report which, in all probability, each member regards as inadequate. Mr. Leighton.

Perhaps the writer's impressions are wrong, but, having had the benefit of acquaintance with some of the members of the Committee, and having, during past years, become familiar with the reputation and accomplishments of the others, he cannot avoid the conviction that this report on floods and flood prevention falls considerably short of the standards to which the Committee members have previously adhered. Such a result is not unprecedented in the lives of busy and well-qualified men.

The subject of floods and flood prevention is each year occupying more of the time and attention of National legislators. Among these

* Discussion of the Progress Report of the Special Committee on Floods and Flood Prevention for 1916, continued from March, 1916, *Proceedings*.

† Washington, D. C.

Mr. Leighton. legislators, doubt and diversity of opinion seem to be growing apace. One who has followed the events in Congress for the past ten years, and who has therefore acquired a mental picture of the legislative situation, must realize that the subject has not progressed to that point of finality with respect to fundamental facts and remedial measures which will insure a comprehensive legislative solution. The flood question crops out in debate on measures both relevant and irrelevant. The same old truths and the same old fallacies are printed each year in the *Congressional Record*. With admirable persistence, Senator Newlands of Nevada presents a great and comprehensive proposal that involves every feature of correction and improvement either closely or remotely related to stream flow and stream utilization. With equal admirable persistence, other Members of Congress advocate divers measures. The House of Representatives has recently created a new standing committee on floods and flood prevention, and it remains to be seen what the practical results of this new move will be. In connection with all this, two truths stand out prominently: First, that the Members of Congress who are expected to legislate wisely in this matter and who, almost without exception, have no engineering qualifications, have the right to expect from the foremost civil engineering society of the country a definite and meritorious expression of opinion that will, in the end, define that which should be done. Second, it is the patriotic duty of every engineer, and certainly of this great National Society of Civil Engineers, to satisfy the reasonable expectations of the legislators.

It does not benefit any legislator to tell him about fundamental principles or to give him a summary of the things which cannot or which should not be done. The legislator is looking for a concrete proposal that will stand the test of analysis. A legislator who may be utterly incapable of formulating a proposal may be quite successful in analyzing, criticising, and pointing out, the weak spots in a proposal submitted to him by qualified engineers. Let us not deceive ourselves about this matter. If the flood problem is to receive final and successful legislative treatment, it will be only after the engineers of the country have come forward with a definite legislative measure, based on physical facts and well-attested engineering principles. This statement may do violence to the sacred tenets of the American Society of Civil Engineers. The writer can already hear the deprecatory expressions of many members with respect to the Society's participation in legislative matters and advocacy of any particular proposal. There is no doubt that such an attitude is comfortable, dignified, and utterly safe, but the fact remains that, if the Society expects to see the consummation of a successful solution of this problem, it must do the useful and necessary thing, rather than the dignified and comfortable one.

Mr. Leighton.

There is no trade or profession in the United States in which one may find such persistent and general expressions of discontent over the inadequacy of legislation as in the Engineering Profession. It is also fair to say that, in the opinion of the writer, there is no profession in which such expressions are so intelligently and considerately given. On the other hand, it is the writer's observation that there is no class of complaining citizens which so consistently fails to come to the aid of legislators with definite concrete advice. If the members of the Society dissent from this statement, let them ask the legislators.

From the foregoing, it will be seen that the writer criticises the Flood Committee's report because it leaves the country and the country's legislators precisely where they were before the Committee undertook its labors. If a traveler who has lost his bearings and has become confused amid a maze of divergent paths, asks the route to his destination, he is not benefited by a reply which says in effect: "Friend, you must take the proper road that leads to your destination; if you go by the wrong road, you will probably not arrive." The writer is very glad that the Committee has been continued, and he submits the foregoing humble suggestions in the hope that they may have some bearing with respect to the future report which it is assumed that the Committee will make.

With respect to the actual findings of the report, the writer agrees in the main with the minority views of Mr. Knowles. Though it is true that many of the sentences which Mr. Knowles proposes in substitution are, in the opinion of the writer, merely improvements in English composition, they do add to the judicial temperament of the report.

The Committee's conclusions (page 2780*) with respect to reforestation may or may not be correct. The writer believes that they are incorrect, but, assuming their entire correctness, it is apparent, to the unbiased readers to whom the writer has submitted this paragraph, that the Committee has either consciously or unconsciously made a seemingly judicial statement which, among legal brethren, would be regarded as a very adroit special plea. The half-truth expressed in this short paragraph does more to convince the reader against reforestation than would the plain blunt statement that forest growth has no effect whatsoever. Paraphrasing the concluding words of the statement, the Committee, with equal truth, could have said: "But there has been no quantitative determination of its influence on stream flow which would justify its exclusion as a method of flood prevention." The writer is familiar with intensive investigations, the results of which have unfortunately never been published, which show mathematically that forest growth does, under certain conditions like those prevailing

* *Proceedings*, Am. Soc. C. E., for December, 1915.

Mr. Leighton. in the White Mountain region of New Hampshire, markedly reduce or meliorate flood extremes.

The Committee has disposed of reservoirs and detention basins as factors in flood prevention by a few short, obvious, and rarely disputed statements. They give the reader the impression that the Committee, on the whole, is doubtful concerning reservoir efficiency; yet, after one thoroughly analyzes the section, he may be able to agree with every statement and still remain a pronounced advocate of reservoirs. This advocacy does not commit any one to the reservoir theory under all circumstances and conditions. It merely commits the believer in reservoirs to the old common law doctrine that every cause is entitled to its day in court. An apparently reluctant admission, such as that made by the Committee, that reservoirs may be beneficial under some conditions, cannot act as a counter-weight to a series of objections and adverse implications which may or may not apply in any particular case. There is, to say the least, a lack of fairness in a pronouncement which gives qualified approval to reservoirs and then cites a series of adverse conditions without also giving to them equal and well-merited qualifications. Altogether, Mr. Knowles' expression "damning with faint praise" is applicable and well-chosen.

The Committee has wisely set forth the deficient and unsatisfactory condition of available stream flow data. It might, with equal wisdom, have set forth the unsatisfactory condition of our knowledge with respect to detailed topography, reservoir sites, and storage management. These deficiencies have been apparent for a score of years. What has the American Society of Civil Engineers done to correct that condition? Federal and State appropriations for such investigations have either been lacking or inadequate, but that is a natural consequence of the lack of information on the part of the people. It cannot fairly be expected that any considerable body of voting citizens is going to become enthusiastic over a fundamental engineering necessity which they do not understand. Who is there to explain and instruct, except the engineers of the country? The lack of appropriations is not entirely responsible for the paucity of data. Some of the blame can be traced to the inefficient expenditure of the money that has been provided. In making this statement, the writer does not intend to reflect on any particular State or Government Bureau, and, if he were disposed to make comparisons, there is one particular Government Bureau which he would exclude from this category, because it has come pretty close to making each dollar produce results to the value of two dollars. The fact remains, however, that engineers, and especially those in official life, have not expended their efforts and appropriations along the most purposeful lines. Looking back over the history of river hydraulics in America, we commonly start with the work of Humphreys and Abbot on the Lower Mississippi.

That classic investigation had one bad result. The engineers accepted it as a finality rather than a most remarkable beginning. Perusal of the reports of investigations that took place during the 25 or 30 years subsequent to the Mississippi investigation will show that the efforts were largely devoted to an attempt to prove how eternally right or how grievously wrong were Humphreys and Abbot. Had our work on river hydraulics during those years been a forward movement, rather than a *post mortem,* our present Committee on Floods and Flood Prevention would undoubtedly have found itself less embarrassed by a lack of fundamental data. A recital of past errors is useful only in so far as it may serve as a guide to future conduct. This Flood Committee could, if it desired, do more than merely report regretfully the deficiencies in our fundamental facts. It could, if it chose, become the fountain head of a campaign by which a beneficial change of conditions could be brought about. Mr. Leighton.

CYRUS C. BABB,* M. AM. SOC. C. E. (by letter).—This report is a good, concise statement of our present knowledge regarding floods and flood prevention methods. It brings out forcibly the lack of adequate engineering data on this extremely important subject. Mr. Babb.

It may be that the data collected by the Special Committee are too voluminous for detailed tabulation in a comprehensive report, but it would seem as though a bibliography or reference table of such data, arranged by drainage areas where possible, might be published with profit to the Society.

It seems to the writer that the Minority Report by Mr. Knowles contains, in a few cases, better expressions for the same ideas than those submitted by the majority. The second heading is a more fair presentation, giving the advocates of reforestation an even standing with the opponents.

The writer is in hearty accord with Mr. Knowles' twelfth heading and of placing it at the end of the report. It would seem as though the U. S. Geological Survey, through its Water Resources Division, was the proper bureau to carry on the investigation. This Division might well be elevated to the rank of an independent bureau, as was done a few years ago in the case of the U. S. Reclamation Service.

KENNETH C. GRANT,† M. AM. SOC. C. E. (by letter).—Experience in connection with flood prevention legislation and investigations has strongly impressed on the writer the value of a carefully prepared report on the general subject of floods and flood prevention, such as has recently been submitted by the Special Committee. Such a report, to measure up to its greatest possible usefulness, should deal with every possible phase of the subject, and should set forth clearly the Mr. Grant.

* Augusta, Me.

† Dayton, Ohio.

Mr. Grant. advantages and disadvantages of every known method of solving the flood problem. It is particularly gratifying, therefore, that the Committee has been continued, with opportunity for written discussion by the membership at large, in order that the Committee may have at its disposal the complete information necessary to make its final report the most comprehensive and authoritative document on the subject to date.

The writer is in accord with the position taken by Mr. Knowles in the second paragraph of his minority report. The report of the Committee will do the most good if it presents both sides of disputed questions, with the reasons for and against, and points out, wherever possible, the line of investigation needed to throw additional light on the problem.

A case in point is the opinion of the Committee regarding the use of reservoirs for more than one purpose. Engineers in America have not had sufficient experience with intensive, extended rainfall and stream-flow studies to enable them to state conclusively that reservoirs cannot be manipulated in such a way by flood-warning stations that part, at least, of their capacity can be used for more than one purpose. The writer has examined a number of large reservoirs which are being operated successfully in this manner in Germany and Austria. Such combined use is especially feasible in regions where floods are confined to one season of the year. Rigid supervision of the construction, and especially of the operation, of such reservoirs by some competent authority is, of course, absolutely essential.

Another case is the treatment by the Committee of the subject of reforestation. The writer would be glad to see the report point out that sufficient data are lacking to prove whether reforestation does or does not regulate stream flow sufficiently to justify its use for that purpose; that if it does have a tendency to reduce flood flow, the partial prevention of floods by such a means would be a slow process, not feasible in any situation where immunity from floods was required at once, although it should be carried out to whatever extent feasible, as a contributory benefit to stream regimen; that reforestation, by preventing erosion, does prevent the filling up of regulated channels, reservoirs, and detention basins, and thus indirectly does assist in flood prevention; that in many cases, even if it were proven effectual, it could not be applied, owing to the value of the lands in the drainage area for other purposes; in short, giving the results of the findings of the Committee on both sides of the question.

An interesting quantitative analysis of the effect of forests on flood run-off was worked up by the French engineers, in studying plans for flood prevention on the Seine, after the great flood of 1910. Their figure for the depth of rainfall absorbed by forest cover was about 0.41 in., to which they added about three times this quantity for the rainfall used up in 10 days by transpiration. With these figures, the action of 10 000 acres of forest cover in preventing run-off is equivalent in 10 days to a storage reservoir capacity of about 60 000 000 cu. ft. Mr. Grant.

The cost of reforesting 395 000 acres in the Seine Basin, including the cost of land, planting, and care, was estimated at $84 400 000. In 10 days this would reduce the flood volume by 2 370 000 000 cu. ft. The cost per million cubic feet of flood water retained by forest cover would thus have been $35 600, about half of which would have been returned in 60 years from the main cut of the timber. This was too high a figure to be considered, especially as the total volume of the 1910 flood at Paris during the maximum 10 days was 70 600 000 000 cu. ft., and during the entire flood was 247 100 000 000 cu. ft.

The French engineers, therefore, recommended that the Government should not take up the reforesting of the Seine Basin directly; especially as they considered that the action of heavy forest cover in retarding run-off disappears almost entirely in the great rainfalls that cause the Seine floods; and also considering the rich agricultural lands that would be taken up for forests. Their decision was that the Government should encourage all works of forest culture, should preserve intact the dense forests then existing, by improving the methods of cutting, and should lighten taxes on forest property.

Popular discussion of the causes of floods has laid so much emphasis on the influence of drainage that it would be helpful if the report discussed this subject. In some cases, properly executed drainage works increase the capacity of the drained lands for retaining water, and improve the soil cover. Furthermore, when irrigation and drainage are combined, increased retention is obtained. In any event, the needs of the improvement of cultivation in most cases notably outweigh any damages resulting therefrom.

As a means of retarding run-off, decreasing erosion and increasing seepage in mountainous and hilly country, horizontal ditches have frequently been discussed by European engineers, but their use has been recommended only in rare cases. Suitable places for utilizing this method are not available to any great extent. They interfere with the use of the ground for other purposes. The cost of construction and maintenance is also too great. If 4 in. of rainfall are to be held back, these ditches must be about 3 ft. deep and 3 ft. wide, and require from one-sixth to one-fourth of the total land surface thus treated. At 30 ft. apart, about 1 450 lin. ft. would be required per acre, or about 928 000 lin. ft. per sq. mile. The cost would be from $13 000 to $26 000 per sq. mile. Such works favor irrigation by keeping up a dampness in the soil and increasing the supply of groundwater. An advantage of this method is that it may easily be carried out by private individuals. It is practised by the farmers of the Cevennes Mountains, in France, and in Tunis.

Mr. Grant. The last paragraph under (*e*) *Levees*, on page 2779,* may be misleading. Unless its exact meaning is studied carefully, it may give the impression that the decrease in valley storage, by confining the water between the levees, had been lost sight of. The comparison between possible methods of protection may be made clearer if it is granted, in the first place, that the lands behind the levees must be given the same protection by each method considered.

Levees of suitable size will protect the low lands behind them. The volume of water stored between the levees will be very great. To give the same protection to these lands without levees would require that this water be stored elsewhere.

It might be stored in a channel excavated to give the same cross-sectional area as that provided between the levees. This would generally be much more costly to build and maintain than the levees. There might be serious complications at the mouths of the tributaries and at the mouth of the river. The ground-water conditions might be very harmfully affected. The added cost at bridges would be very great.

It might be stored on the drainage area above, if sites could be found. The total capacity of such storage basins would have to be much greater than the storage space between the levees, in order to take care of variations in distribution of flood rainfall, and to make up for the reduction in the effect of storage that takes place in passing down stream.

One statement in the paragraph alluded to may be questioned, unless the writer has not fully gathered its meaning, namely, at the end of the first sentence: "the resultant reduction of flood height from this cause". It is unquestionably true that the artificial storage between the levees is not so great as the natural storage that was available over the lowlands along the river before the levees were built, and that this reduction in storage raises flood heights. At the same time, the contraction of the flood flow between levees raises flood heights at and up stream from the stretch of river that has been leveed. When adequate levees are built to above this increased flood height, and properly protected and maintained, they afford one of the surest and safest means of flood protection.

In view of the action of levees in reducing natural storage and thus increasing flood heights, especially in the river below, proper precautions should be urged that such improvements be not made on any reach of a river until adequate provisions have been made at other points to take care of the changed conditions of flood flow. There are points here which can well be considered in discussion of the Report of the Special Committee on A National Water Law.†

* *Proceedings*, Am. Soc. C. E., for December, 1915.

† *Proceedings*, Am. Soc. C. E., for December, 1915, pp. 2747–51.

Mr. Grant.

The French water laws specifically name what rivers or stretches of rivers may not be leveed to above maximum flood stage. On the Loire, wide overflow spillways have been provided on the levees to allow temporary storage in the lowlands behind them during extreme floods. It has for years been a subject of discussion and investigation in Austria and Germany as to whether the levees could not be altered so as to keep out only the lower floods of the growing season, and allow the great winter and spring floods to overtop the levees and spread over the lowlands. The reduction of flood heights thus obtainable is one argument in favor of such treatment; another is the fertilizing action of these silt-laden waters on the lowlands behind the levees, and great stress is laid on this feature in all reports on the subject. The overflow areas in the German river valleys are to-day only about one-fourth to one-fifth of their natural and original extent.

The natural storage effect on the overflowed lowlands along a river may be very considerable, and may have an appreciable effect in lowering flood heights. In the Miami Valley above Dayton, the valley storage in the 1913 flood amounted to about 300 000 acre-ft., or 32% of the total run-off from the 2 500 sq. miles above Dayton during the maximum 3 days of the flood.

On some rivers a disadvantage of building levees reaching to above high water is that the lowlands behind the levees are no longer raised by deposits, and sometimes even sink lower; and the river itself may gradually raise its bed by deposits in its middle and lower course, where the slope is flat. These lowlands can even gradually become swampy, and the pumps formerly used for freeing them of water in the spring only will have to be kept at work longer. This is especially to be feared in the lowlands on low deltas, which are gradually extended into the sea by deposits of silt, so that the raising of the water surface in the river is necessary, in order to create the fall required for discharge through the longer channel.

On the other hand, the narrowing of the channel by levees, by increasing the velocity, is oftentimes not only favorable for transportation of silt, but indeed forms the only available means for preventing a raising of the river bed. Without the levees, the banks and land immediately bordering them would be gradually raised, and lowlands farther back would remain low; and sometimes rivers would break through and seek a new channel in the lowlands, with disastrous results. This danger is especially great in the upper courses of rivers, where the slope is steeper. The levees reaching to above high water there form the only effective means of preventing this.

In channel improvement by deepening and straightening, due consideration should be given to the effect on ground-water conditions. On the Weser River, in Germany, agricultural interests have required

Mr. Grant. large expenditures in order to restore the ground-water conditions that obtained before the channel was deepened.

It is important, in connection with later plans for channel improvement, that some suitable agency be authorized to exercise control over the placing of obstructions in and along streams. The cost of adequate channel improvement in some localities is greatly increased, and sometimes made prohibitive, by structures that should never have been allowed to be built in their present location or to their present dimensions.

On some rivers, particularly where melting first takes place on the upper river, as on the Oder and Weichsel in Germany, the formation of ice jams is a frequent cause of floods. The design of improved channels on such rivers should take this into consideration. In special cases ice-breaking steamers may be found necessary to prepare for spring freshets from the upper river.

Detention basins as a means of flood control are stated by the report to be successful in certain localities. This method, as yet little used in America, should perhaps be discussed in more detail. There are localities where this is the only kind of storage feasible. The agricultural lands may be too valuable to be dedicated to permanent storage. Floods may not be confined to any one time of year, so that where the drainage areas controlled are small and floods collect too rapidly to permit the emptying of a partly full reservoir in time to provide the required flood storage space, all the capacity intended for flood control must be kept empty, and ready for immediate use. In such cases, if the entire capacity available is required for flood storage, a "dry" reservoir is the only type feasible. Detention basins, as compared with reservoirs, have the disadvantage of wasting the stored flood water; and in some localities this may be a very important consideration; but, where the foregoing conditions prevail, and where flood control is a vital enough issue to warrant their construction, they will sometimes be found the best solution of the problem.

Where assurance can be had of competent and permanent supervision and maintenance, detention basins can be made much more effective by providing artificial control. Where there are no gates in the outlet conduits, they must be designed so that the maximum flood will just reach the spillway when the inflow has fallen to the same rate as the outflow. This, however, gives a much less degree of control over smaller floods than could be obtained by the manipulation of gates in the outlet conduits.

The great advantage of detention basins is that they do not remove the land in the basins from cultivation. In the Miami Valley, where the conditions for this method of flood control are particularly favorable, the total area flooded in the five proposed basins, with a flood like that of 1913, would be 29 850 acres. More than 60% of this same land (18 700 acres) was actually flooded in 1913. After such a flood all the

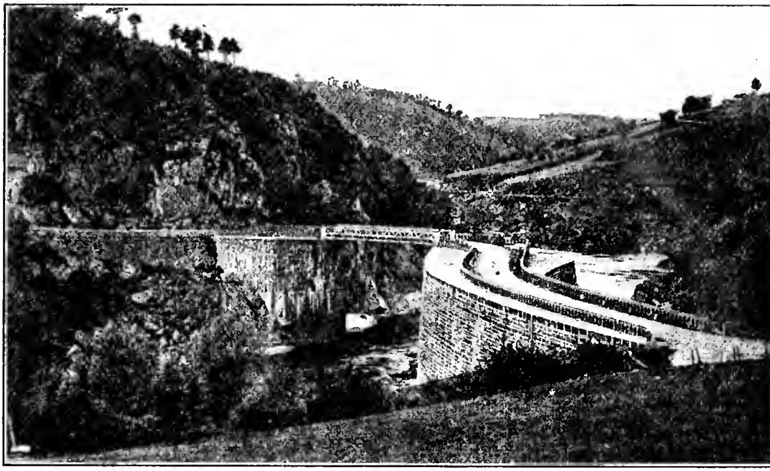

FIG. 1.—PINAY DAM ON LOIRE RIVER ABOUT 7 MILES ABOVE ROANNE, FRANCE.

FIG. 2.—TYPICAL EXAMPLE OF WORK OF REFORESTATION AND MOUNTAIN-TORRENT CONTROL ON HEAD-WATERS OF ELBE RIVER.

reservoirs except one would empty again in a week, and that one would take about 3 weeks. In smaller floods, they would flood less land and empty much more rapidly; and, even in extreme floods, a large part of the area would be flooded for only a few days. The area actually flooded in 1913 in the Miami Valley above Hamilton was 63 000 acres, or more than twice as much as would have been flooded in the detention basins if they had been in operation. Of this flooded area, 13 000 acres were in cities and towns. Mr. Grant.

Fig. 1 shows the Pinay Dam, on the Loire River, about 7 miles above the City of Roanne in France. This is one of the most interesting examples of a detention basin in Europe. It was built by the French Government in 1711, and has since repeatedly saved the city from destruction.

It should be pointed out, in discussing reservoirs, detention basins, and levees or other channel improvements, that in many cases no one method may provide an adequate solution of the flood problem, but the best plan will consist of a combination of two or more methods. It may be found unfeasible or uneconomical to reduce flood flow to existing channel capacities by reservoir or detention-basin control. It may be found equally unfeasible or uneconomical to provide an adequate channel to accommodate maximum floods. Protection by one method is best carried out up to the point where the remaining necessary protection is cheaper by some other method.

In discussing the function of barriers in mountain streams, their action in increasing soil absorption should be included. Under certain conditions, as in Los Angeles County, California, this may be very considerable, and may bear an important relation to other phases of the water problem.

The important action of barriers in holding back sand, gravel, and boulders from improved channels and reservoirs below should be brought out more definitely. In some of the comprehensive river improvements of Europe, reforestation and *Wildbachverbauung* form an integral part of the reservoir systems and channel improvements, and are regarded as essential to the maintenance of such works on the lower streams. The River Regulation Commission of Bohemia has been carrying on a remarkably well co-ordinated work of this character on the upper Elbe, including reforestation, barriers on mountain torrents, flood-control reservoirs and channel improvements.* Fig. 2 shows a typical example of the work of reforestation and mountain torrent control on the head-waters of the Elbe.

The report makes no reference to the method of reducing floods by spreading over permeable strata. It would be helpful if it would take up the advantages and disadvantages of this method and its re-

* *Engineering News*, October 15th, 1914.

Mr. Grant. lation to underground storage, and make some reference to localities where it has been or might be applied successfully.

Desynchronization of tributary flood peaks is an effective means of flood prevention in particular cases. It will generally be insufficient by itself, but will lessen the work to be done in connection with other methods with which it may be combined. In mountain streams, tributary flood peaks that reach the main stream at or after the passage of the flood peak of the latter can be retarded further by barriers or small detention basins, and those that arrive early can be accelerated by the improvement of their channels.

The same process on a large scale can sometimes be carried on with the larger streams, farther down. A flood wave can be made to travel twice as fast without any increase in the average velocity of the water, by establishing the proper cross-section. It can be demonstrated that, with a parabolic cross-section the speed of propagation is approximately four-thirds of the average velocity. Tributaries that deliver their flood peaks early can thus be further accelerated without any increase in erosive action. Other slower tributaries can be further retarded, where feasible, by reservoirs or detention basins, or by wide overflow areas along the banks.

Obviously, in solving the flood problem of any river basin, it is very important to avoid the more perfect synchronization of tributary flood peaks that might be brought about by reversing the treatment just outlined. It would be dangerous, for example, to construct detention basins or provide overflow areas on tributaries delivering their flood peaks early, unless the basins were large enough and the outlets small enough to reduce the flood wave sufficiently to preclude any possibility of aggravating the flood conditions on the main stream. In the same way, as a general principle, it would be unwise to speed up the flood wave on a slow tributary.

The report might well include some reference to flood prediction and its value in preventing or reducing flood damage. This is a measure of relief that can be applied at once, pending the construction of flood prevention works. It has been very thoroughly worked out in some European countries, but has not yet been developed to its full possibilities in the United States.

The figure quoted in the report for the flood losses in 1913 in the Ohio Valley is much too small. The direct property loss in the Miami Valley alone was about $70 000 000, and to include the loss through depreciation would greatly increase this figure.

The writer joins most heartily with the Committee when it urges more thorough, intensive, and co-ordinated studies of matters relating to flood control. Such investigations should include all data necessary for the solution of problems of water conservation and stream control, in order that flood prevention works may be co-ordinated with other uses of the streams. Enormous appropriations for river regulation and water conservation have been urged before Congress for some years. If these appropriations were to be made to-day we would not have the data with which to design, intelligently and economically, the works to carry out the purposes thereof. The proponents of such measures would do far more good in the development of the country's water resources if they fathered successfully a bill appropriating several million dollars a year for the use of the present Government agencies now struggling to collect data with pitifully inadequate funds for operation. Mr. Grant.

In nearly every problem of river control attacked by the engineer in America, he finds himself confronted with almost a blank wall of lack of data, and is obliged to make safe assumptions that greatly increase the cost of the work. River gauging stations are too widely scattered, and lack of funds prevents their efficient operation. At many of them the gauge is read but once daily, so that there is no complete record of flood peaks, as they frequently occur between readings. The number of rainfall stations should be very largely increased, and hourly readings should be taken during rain storms. It is not possible, with the present methods of collecting and recording rainfall data in the United States, to determine successfully the relation between rainfall and run-off.

The writer would be glad to see the report make definite recommendations to remedy this condition.

B. F. Groat,* M. Am. Soc. C. E. (by letter).—A reading of the Progress Report of the Special Committee on Floods and Flood Prevention, the Minority Report by Morris Knowles, M. Am. Soc. C. E., and the subsequent discussions by Messrs. Eakin and Hill, discloses the fact that the report does not seem to cover all the ground expected, and that possibly suggestions in more definite language as to general policies and methods would be acceptable. Mr. Groat.

It appears to the writer that the whole question of flood control is necessarily indefinite at present and probably will so continue for a long time. The indefiniteness and uncertainty of such a report, therefore, is a natural and certain consequence of the circumstances and present state of knowledge of the subject, rather than a result of any neglect or lack of thoroughness on the part of the Committee. Under the circumstances, one can scarcely expect a committee to devise revolutionary constructive policies, or express conclusive opinions, concerning a question which has perplexed all the rest of the world since the idea of national flood control developed and raised itself from a special to a general engineering problem, intimately related to that of national conservation. At least, this is the opinion of the writer, who is more or less of an exoteric with regard to this particular subject.

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* Pittsburgh, Pa.

Mr. Groat. Mr. Knowles' objections to the report appear to be based largely on phraseology which he considers to be single-viewed, and to partake, so to speak, of the prejudice of the Committee. The writer believes that a committee report is no place for the individual opinions of the members, except when expressly stated to be such, and that where controversial matter is involved, the evidence on both sides should have equal publicity. Engineering questions are not to be settled as are questions of law—by arbitrary rule—but they should lead to the determination of a rule, or procedure, which shall meet with either general approval or the specific approval of the Engineering Profession.

As regards breadth of view, there does not appear to be much room for exception, and it must be observed that, with the amendments suggested, the report would be even more indefinite than without, as should be expected in the case of this subject, except that Mr. Knowles does ask for additional kinds of data, as well as an increase in the quantity of such data as are now regularly observed by various agencies. The Government agencies might increase the variety by adding such information as data on erosion and transportation, precipitation for various altitudes at the same place, and for different places and circumstances, especially in higher altitudes and in sparsely settled districts. Some systematic method might be recommended for the study of forest reaction.

The most important policy suggested by Mr. Knowles is that briefly outlined in the last paragraph on page 2787.* It appears to be admitted by all that the whole question of floods and flood prevention is of vital importance, and demands special efforts and expenditures commensurate with the difficulties encountered. Why not, therefore, have a "special agency, supported by adequate appropriations, for the purpose of studying stream regulation in its largest sense?"

* *Proceedings*, Am. Soc. C. E., for December, 1915.

MEMOIRS OF DECEASED MEMBERS

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

WALTER FRANK CARR, M. Am. Soc. C. E.*

Died February 2d, 1916.

Walter Frank Carr was born in Holyoke, Mass., on January 1st, 1861. He was the only son of Francis E. Carr, who married Sarah Kittridge, at Clinton, Mass., in 1860.

Mr. Carr's early education was received at Clinton, Mass., and he was graduated from the High School in 1878. He then entered the Massachusetts Agricultural College, at Amherst, from which he was graduated in 1881. Afterward, he entered the Massachusetts Institute of Technology, and received the Engineer's degree in 1884. His graduation thesis was on the sewerage system for his home town, Clinton. When that city took up the matter, later, it was decided to accept Mr. Carr's work as the basis for the new system, which was built and is still working successfully.

From 1884 to 1885, he was Assistant Bridge Engineer on the old Boston and Lowell Railroad, now a subsidiary of the Boston and Maine Railroad. From 1885 to 1888, he was Professor of Engineering at the University of Minnesota. In August of the latter year, he returned to railroading, as Assistant Engineer of the Minneapolis and St. Paul Street Railroad Company, and two years later was appointed Chief Engineer. In this capacity he had supervision over the electrification of 190 miles of road, including overhead and track construction, power-houses, design of rolling stock, etc.

In 1888, Mr. Carr laid out what is now the Washburn Park Addition to Minneapolis, Minn. This was one of the first attempts ever made in the United States to lay out a city on the basis of landscape architecture, and it is still considered one of the prettiest of city additions. In 1889, he laid out Horseshoe Island Park, at Eau Claire, Wis., which was also according to the "City Beautiful" idea. Both these parks are residence additions.

In December, 1891, he became General Manager and Chief Engineer of the Roanoke (Va.) Street Railway and the Roanoke Electric Light Company, and supervised the reconstruction, extension and operation of the system. It was during this year that he designed the first "Shanghai" Tee-rail now so commonly used.

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* Memoir prepared by Bertram D. Dean, M. Am. Soc. C. E.

Between March 1st, 1895, and June 1st, 1896, Mr. Carr was Superintendent of electric construction of the West Chicago Street Railway (Yerkes' System), covering the period of the change in motive power from horse to electricity. He also superintended the electrification of the Lake Street Elevated Railroad (Chicago and Oak Park Railroad). In June, 1896, he was appointed Chief Engineer of the Yerkes Company, filling that position until April, 1899.

At the time of the organization of the Falk Company, Milwaukee, Wis., steel founders and manufacturers, in 1899, Mr. Carr took a financial interest in that Company, and was appointed Chief Engineer, which position he held for twelve years. During that period he had entire management of the Frog and Switch Department, and of the contract work in the construction of city and interurban railway systems. In 1902, he accomplished one of the most difficult engineering feats of his career. In Kansas City, Mo., it was necessary to shift a two-track system from the side to the middle of the street. It was a cable-power road traversing the down-town district, and the entire work was accomplished, without interrupting regular service in the slightest degree. In 1909, he designed and patented the first three-way switch ever constructed.

During the last four years, Mr. Carr was on the Pacific Coast, for two years as Manager of the Railway Department of Parrott and Company, with headquarters in San Francisco; later, as Pacific Northwest Manager of the Western Engineering Sales Company, with headquarters in Seattle. He also practised as a Consulting Engineer, specializing in valuation of railways and public utilities.

At the time of his death, Mr. Carr was a member of the National Geographic Society, the Engineers' Club of San Francisco, Engineers' Club of Seattle, Railway Signal Association, Technology Club of Seattle, Municipal League, Eureka Lodge No. 20, F. and A. M., and other organizations.

He was married in 1885, to Alice Merril, at Mansfield, Mass. Mrs. Carr died two years later. On May 28th, 1890, he married Elizabeth Gardner, of Minneapolis, Minn., who, with three sons, Gardner, Alan, and Burton, survives him.

Mr. Carr was a man of high ideals with a keen conception of his profession. Strength and clearness formed the basis of his daily work; his standard was that of honesty and truth. His modest, lovable disposition endeared him to all. To his many friends, his passing away is a source of great sorrow, but they have the consolation of knowing that it had been their privilege to work and walk with so interesting a man.

Mr. Carr was elected a Member of the American Society of Civil Engineers on June 6th, 1894.

WILLIAM WEEDEN COLE, M. Am. Soc. C. E.*

Died December 20th, 1915.

William Weeden Cole was born on April 4th, 1866, in Medford, Mass., of Revolutionary stock. He acquired his technical education at the Worcester Polytechnic Institute, with the Class of 1887. After leaving college, he was employed as Assistant Engineer with the New England Construction Company, in charge of water-works construction and operation, at Newport, R. I., Gloucester, Mass., Frankfort, Ind., and Green Bay, Wis. He was subsequently with the Toledo, St. Louis and Kansas City Railroad, as Division Engineer, but, owing to an injury received in this service, returned to Boston and entered the employ of the Thompson, Houston Company, with whom, after three months' factory service, he became Superintendent of Electrical Affairs on the Alston Division of the West End Street Railway.

In 1892 Mr. Cole became General Manager for the Utica Belt Line Railroad, and a year later designed and built the West Side Street Railway and the Elmira Heights Water-Works, at Elmira, N. Y. During the next sixteen years he was associated with the Public Utility Companies in Elmira, being instrumental in consolidating the street railways, electric light companies, natural and artificial gas companies, water-works companies, and park properties, into one consolidated Utility Corporation, and served as Vice-President and General Manager of these properties. During a large part of this period, he also acted as Consulting Engineer for the Chemung Canal Trust Company, of Elmira, in connection with its various investments.

In 1907 Mr. Cole left Elmira to become a member of the firm of Day and Zimmerman, of Philadelphia, Pa., well known in engineering and public utility circles. He acted as Manager of their Public Utility Department, and remained with them in that capacity for seven years. The organization of the Pennsylvania Central Heat, Light and Power Company, which includes a number of electric light and gas properties, also the reorganization and reconstruction of the Electric Light and Traction Companies of Oil City and Franklin, Pa., were effected by Day and Zimmerman during Mr. Cole's management of their Public Utility Department.

Returning to New York, Mr. Cole, in January, 1915, entered into a partnership with Messrs. Arthur S. Ives and Rolland A. Davidson, who had previously been associated in engineering work, and the new firm of Cole, Ives and Davidson has continued to specialize in public utility engineering work and in financial reports for prominent banking interests.

* Memoir prepared by Arthur S. Ives, Esq.

In addition to his other activities Mr. Cole acted at different times as Consulting Engineer for various financial interests in connection with appraisals, examinations, and reports on gas, electric, and traction properties, including the utilities at Canandaigua, N. Y., Hartford, Conn., Lancaster, Pa., Colorado Springs, Colo., Lockport, N. Y., Topeka, Kans., Terre Haute, Ind., Denver, Colo., Baltimore, Md., Beloit, Wis., etc.

Mr. Cole was also the first President of the Empire State Gas and Electric Association, of New York, and Vice-President of the New York Street Railway Association. He was a member of the American Society of Electrical Engineers, National Electric Light Association, Illuminating Engineering Society, American Water Works Association, Engineers' Club of New York, Racquet Club of Philadelphia, Elmira City Club, Venango Club of Oil City, Railroad Club of New York, and others. He was also a thirty-second degree Mason.

Mr. Cole had a most winning personality and a host of friends. He had a persuasive manner which, both in business and in his social life, kept him surrounded by those who could not help but be attracted by the exquisite wit and story-telling ability which he so largely possessed. He was a brilliant public speaker and possessed of a most remarkable memory; he had a marvelous faculty of quoting statistics, a constant source of wonderment to his engineering friends, and with a corresponding effect on his clients and laymen with whom he came in contact.

Mr. Cole had also a faculty which excited the greatest comment, in that, when he was making an engineering examination of a property, he was never known to make notes or memoranda, yet his reports were replete with data that could only be secured by personal observation and held by his retentive memory. He seemed to have an intuitive judgment in such matters, which was so invariably correct as to win and preserve the confidence of the large financial interests for whom he did so much of this work.

He was married on June 14th, 1889, to Miss Agnes Cornelia Barker, of North Granville, N. Y., who, with two sons, Norman Weeden Cole and Lester Weeden Cole, survives him.

Mr. Cole was elected a Member of the American Society of Civil Engineers on October 7th, 1903.

EMORY ALEXANDER ELLSWORTH, M. Am. Soc. C. E.*

DIED DECEMBER 8TH, 1915.

Emory Alexander Ellsworth, the son of John F. and Maria (Lawrence) Ellsworth, was born in Hardwick, Mass., on August 3d, 1852.

* Memoir prepared by J. W. Tower, M. Am. Soc. C. E.

He was educated in the schools of his native town, and was graduated from the Massachusetts Agricultural College at Amherst, in the Class of 1871, this being the first class to be graduated from that institution.

In 1872, Mr. Ellsworth began work as an Assistant on the construction of the water-works for Holyoke, Mass., and from 1873 to 1876, was a member of the firm of Davis and Ellsworth, engaged in general engineering practice in Holyoke.

In 1876, he left engineering and became a traveling salesman, following this work until 1880, when he returned to the Profession as Section Engineer for the New Haven and Northampton Company, now the New York, New Haven and Hartford Railroad Company, on construction of the then new railroad from Northampton to Turners Falls, Mass.

From 1881 to 1884 he was Principal Assistant Engineer for D. H. and A. B. Tower, Architects and Mill Engineers, at Holyoke, Mass.

In 1884, Mr. Ellsworth was elected City Engineer of Holyoke, Mass., which position he held for five years. As City Engineer, he was also Engineer for the Water-Works. While he occupied this position he designed several city school and fire department buildings, also three reservoir dams for the water supply system.

In 1890, he resumed private practice in Holyoke which he continued until 1901, when Mr. John J. Kirkpatrick became associated with him under the firm name of Ellsworth and Kirkpatrick. This arrangement continued until May 1st, 1907, when Mr. Kirkpatrick retired.

After Mr. Kirkpatrick's withdrawal, the firm became Ellsworth and Howes, with Mr. Lyman R. Howes as Junior Member. This partnership continued until Mr. Ellsworth's death, which occurred at his home in Holyoke, Mass., on December 8th, 1915.

He was the Architect for several of the buildings of the State Insane Hospital at Northampton, Mass., also for the Massachusetts College at Amherst, Mass., and designed several paper and textile mills.

Mr. Ellsworth was of a quiet, unassuming disposition, and a hard worker. He was devoted to his family and home.

He was twice married, first to Miss Lucy J. Bradford, who died in 1900, and, in 1902, to Miss Carrie Meach, who survives him. By his first marriage there were two sons and one daughter, all of whom are living, together with five grandchildren.

He was a Member of the Boston Society of Civil Engineers and a Charter Member of the Bay State Club of Holyoke.

Mr. Ellsworth was elected a Member of the American Society of Civil Engineers on June 1st, 1904.

BERNARD RICHARDSON GREEN, M. Am. Soc. C. E.*

Died October 22d, 1914.

In the death of Bernard Richardson Green, a former Vice-President of this Society, this country lost an able civil engineer and a conscientious, devoted, and modest public servant; his associates, a wise and experienced counsellor; the community in which he lived, a generous, unselfish, and public-spirited citizen; and his friends, a loyal, frank, and gentle companion.

He died at his home in Washington, D. C., on October 22d, 1914, in the seventy-first year of his age, having been born on December 28th, 1843. He is survived by his widow, Julia Lincoln, to whom he was married in 1868, and by one daughter and three sons.

His birthplace was Malden, Mass., the home of his parents, Ezra and Elmina (Richardson) Green. From the public schools, where he obtained his earlier education, young Green went to the Lawrence Scientific School, which he attended as a student in Engineering from 1861 to 1863.

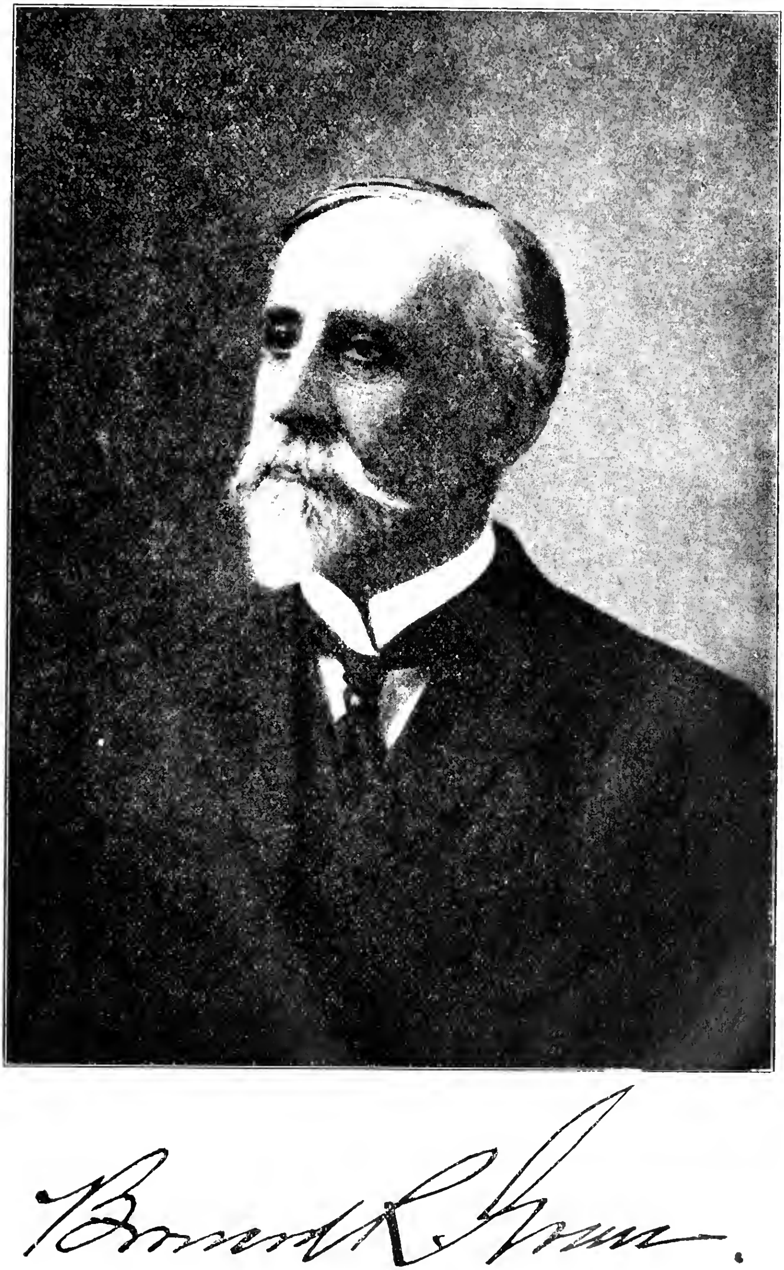
In 1863 he entered the service of the United States Government, in which he remained for more than half a century. He began his service as a Civilian Assistant, under the Corps of Engineers of the Army, and for 14 years he was mainly engaged in the construction of permanent sea coast defenses on the coasts of Maine, New Hampshire, and Massachusetts. During this time he acquired a thorough knowledge of governmental methods of procedure in public works, a knowledge which is of great importance in government work, and the lack of which has often hampered civil engineers who have not learned to unravel the mazes of red tape so as to keep it from stifling the economy and efficiency which is the pride of our Profession.

Although at first serving under the Corps of Engineers of the U. S. Army, and associated with it for the greater portion of his career, Mr. Green was never a member of that Corps, but always a civilian. Therefore, the military title by which he was sometimes addressed was erroneous.

In 1877 his activities were transferred to Washington, where he distinguished himself as an architectural engineer in the building of many notable government structures. The earlier of these were erected under the general direction of Lieut.-Col. Thomas Lincoln Casey, Corps of Engineers, U. S. A., who later became Chief of Engineers. From then until Gen. Casey's death Mr. Green was his Assistant.

Mr. Green began his duties in Washington at a period when official architecture did not concern itself with the homogeneity of design

* Memoir prepared by the following Committee: O. H. Tittmann, George F. Swain, and Clifford Richardson, Members, Am. Soc. C. E.



for government buildings there. One of these, known as the State, War and Navy Building, departing widely from the architectural spirit of the Treasury Building and the White House, but flanking the latter, had been commenced, and to Mr. Green was assigned the task of completing the huge structure. The design had been already sanctioned and adopted by the government, and in part carried out by the construction of the south and a part of the east wings of the building, before Col. Casey was charged with the prosecution of the work which he entrusted to Mr. Green. Although hampered by existing contracts and by precedents established in the completed part of the building, Mr. Green introduced new methods and, by his circumspection and efficient management, finished the structure at a cost so much smaller, proportionally, than that incurred in the construction of that portion of the building already finished, as to save the government several millions of dollars.

Mr. Green's name is also inseparably connected with the construction of the Washington Monument. The weather marking of the lower part of the monument plainly shows to this day how far the obelisk had progressed before the National Government undertook its completion. The site of the monument was on low, alluvial ground, and before work was resumed, it was found necessary to strengthen materially the old stone foundation under that part of the shaft built by the predecessors of the engineer destined to complete it. In searching for a satisfactory method of accomplishing this, engineers throughout the country, both in the U. S. Service and in civil life, were invited to make suggestions. Of those submitted, however, the method proposed by Mr. Green was adopted as the most practical. He undermined the old stone foundation, excavating narrow sections, on opposite sides at a time, until there had been provided a broad and deep concrete base, amply sufficient for the entire load of the shaft when completed. Although the portion already built was found to be nearly 2 in. out of plumb, the operations under the footings were balanced so nicely that on their completion, the error was substantially corrected and the shaft was almost perfectly vertical. There has been no settlement since. Although Mr. Green was not directly in charge of these operations, he nevertheless maintained a general supervision of the entire completion of the monument. He designed the very unique and extremely light marble pyramidion which completes the obelisk, also many less important details of its construction; and, later, when the shaft suffered a stroke of lightning by which one of the pyramidion stones was dislodged, he supervised the repairs and the installation of an entirely new system of protection from lightning, which has proved entirely satisfactory.

Mr. Green's connection with the completion of the State, War and Navy Building is mentioned in order to illustrate the manner in which he gained his well-earned reputation for ability and organizing talent; his connection with the building of the Washington Monument is mentioned because his relation to the completion of that beautiful shaft should be remembered by the thousands of his countrymen who visit it. During the time that he was acting as assistant and professional adviser to Col. Casey, however, he supervised the construction of other buildings, such as the Army Medical Museum and some of the principal buildings in the Soldiers' Home. At the same time, his professional advice was freely sought in Washington and elsewhere in matters unrelated to the government.

During the last twenty-five years of his life his energies were devoted mainly to the building for the Library of Congress, although his professional service was extended to many other fields as well. He was in charge of the construction of the Library Building, and later superintended all the maintenance and repairs, and the expansion of its book-stack capacity. Many of the interior appointments, and especially the scheme of storing and delivering books, give testimony to his originality and thoroughness. The whole structure, as a library plant, has been a model for most of the library construction undertaken since.

His connection with the Library began in the spring of 1888, when he was asked by a committee of Congress to examine and report on the condition of the work already accomplished, and estimate the probable cost of the building if carried out in accordance with the plans then in force. After his report had been received and considered he was invited to take charge of the construction of the building from modified plans to be prepared by an associated architect along the lines suggested in his report. In the autumn of 1888, however, Gen. Casey having returned to Washington as Chief of Engineers, the entire control of this undertaking was placed in his hands by Act of Congress.

Gen. Casey immediately entrusted the execution of the work to Mr. Green, and he was in direct responsible charge of it until Gen. Casey's death early in 1896. Thereupon, by Act of Congress, Mr. Green was appointed to the entire control of the construction. The building was finished in 1897, well within the estimated time and cost, and with remarkable economy. He was then given charge of its maintenance, with the title of Superintendent of the Building and Disbursing Officer of the Library, and this office he held at the time of his death.

Among his other activities in later years were his supervision of the construction of the Pennsylvania State Capitol at Harrisburg, Pa., and an examination and report on the new State Capitol at Jackson, Miss.

His portrait makes a description of his personal appearance unnecessary. He was a man of commanding presence, 6 ft. tall, and well-proportioned. He was as gentle in his manner as he was firm of purpose. He loved music, and gave freely of his time and means to promote a taste for its refining and ennobling influence. He was long associated with the Washington Choral Society, to which he gave his help and counsel.

He was a Trustee of the Corcoran Art Gallery, was active in the scientific societies of Washington, and was one of the founders of the flourishing Washington Society of Engineers. In 1899 he was President of the famous Cosmos Club.

When Mr. Green had completed a half century of service, on March 7th, 1913, some of his friends, all well-known men, gave expression to their high regard for his abilities and character in a signed testimonial which may fittingly close this brief sketch of his career:

"On this day you will have completed fifty years of service to the United States. To few indeed has such a term been vouchsafed, and, while the individual qualities which have characterized your own relation with the government are happily not unique in its history, few men indeed, can show a record which combines qualities so useful in a union so complete of inventive skill, technical knowledge, executive energy, simplicity in method, firmness without bluster, persistent and unselfish devotion, inflexible integrity, and a modesty more than content to be anonymous.

"The permanent memorials of these qualities are in stone and marble. They are in structures of beauty, of dignity, and of efficiency, with which your name will forever be associated. But the friends of yourself and of the public service whose names are signed below, usurping a privilege in which scores of others would have been glad to join, desire to offer you their acknowledgments, their congratulations, and their warmest wishes, and to couple with these a memento of the day which will, they hope, help to divert such leisure hours as you may allow yourself hereafter."

Mr. Green was elected a Member of the American Society of Civil Engineers on October 2d, 1889. He served as a Director for three years (1894-95-96) and as Vice-President for two years (1906-07).

THOMAS FRANCIS McCRICKETT, M. Am. Soc. C. E.*

DIED JANUARY 26TH, 1916.

Thomas Francis McCrickett, the son of Patrick and Sarah O'Flynn McCrickett, was born in Detroit, Mich., on November 9th, 1869. In early infancy his parents took him to Bay City, Mich., and it was there

* Memoir prepared by Richard H. Daly, Esq., Eng. Dept., Russel Wheel & Foundry Co., Detroit, Mich.

that he received his primary education. He was one of the first boys to be graduated from St. James School of Bay City, the pioneer parochial high school of the country, and he was as proud of his membership in the alumni of this institution as he was of any affiliation that was his. After his high school term, Mr. McCrickett spent a few years as a teacher in the country schools of Bay County, Michigan. This was an experience to which he always looked back with great pleasure, and one which he prized as among the most valuable of his life. Then came a term at Alma College, Alma, Mich., followed by his entrance into the Engineering Department of the University of Michigan. As proof of his high rank as a student and of his scholarship, two things may be related: The first is a quotation attributed to the Dean of Engineering at Ann Arbor, Professor Cooley—"Students may come and students may go, but there will never be another Tom McCrickett." The second is Mr. McCrickett's election to membership in the Tau Beta Pi Fraternity.

Mr. McCrickett's first position after leaving the University was with the Industrial Works, the leading manufacturing institution of Bay City, Mich. He remained there about one year, at the end of which period Mr. W. S. Russel, of the Russel Wheel and Foundry Company of Detroit, chose him as engineer to take charge of his growing business in the structural steel line. This choice marked the beginning of a term of service through which Mr. McCrickett won for himself a reputation as an engineer of great ability and a business man of impeccable integrity. He won likewise the esteem and admiration of his employer to the extent that the official announcement of cessation of activities at the Company's office on the day of the funeral referred to him in these words: "our beloved officer and companion". Indeed, the man and friend stood out pre-eminently in Thomas McCrickett.

Mr. McCrickett died on January 26th, 1916, at Harper Hospital, Detroit, Mich., the end coming as the result of an operation for intestinal trouble. By his death the Society has lost a worthy and distinguished member, and the Engineering Profession has been deprived of the services of a worker of mark and capacity.

Mr. McCrickett at the time of his death was at the head of the Engineering Department of the Russel Wheel and Foundry Company, one of the largest fabricators of structural steel in the country. This position he had held for a number of years, and there are in the City of Detroit, throughout the State of Michigan, and in spots scattered here and there all over the land, many a quasi-imperishable monument of steel, attesting the proficiency of this engineer, whose task it was to solve the problem of what these sky scrapers, bridges, power-plants, viaducts, auditoriums, and the like should be in order to serve the purpose for which they were constructed.

Although Mr. McCrickett was an engineer of eminence, he was not engrossed in his profession to the exclusion of all else. All that was worthy in the thought or action of the community in which he lived had his ardent support. He was a zealous worker in the St. Vincent de Paul Society; he was first officer of the Detroit Assembly of the Knights of Columbus; and was an enthusiastic member of the University Club. These affiliations were as much a part of his life and labors, and are as worthy of note, as his membership in the Detroit Engineering Society, of which he was a Past-President, and his place on the faculty of the Engineering Department of the University of Detroit.

He was an engineer by profession, and merited distinction among his colleagues; yet he will live in the memory of those who knew him best as an exemplar of sterling manhood, and as a generous, trustworthy, and reliable friend.

Mr. McCrickett was elected a Member of the American Society of Civil Engineers on January 2d, 1907.

CHARLES PERKINS WEBBER, M. Am. Soc. C. E.*

Died January 30th, 1916.

Charles Perkins Webber, son of the Rev. Putnam Webber, of North Andover, Mass., was born at Hudson, Mass., on November 18th, 1876. From September, 1898, to June, 1902, he was a student in the Civil Engineering Department at Brown University, but, owing to illness and the loss of a term during his Junior year, he did not receive his degree.

On leaving college Mr. Webber went to Mexico, and, from June, 1902, to June, 1904, was employed on the Mexican Central Railroad as Assistant Division Engineer. He was engaged on the construction of the Lecheria-Sandoval Branch from June to September, 1902; was Division Engineer in charge of the construction of 30 km. of the road from September, 1902, to October, 1903; was Track Engineer on the San Pedro Branch from October to November, 1903; and Topographer, Leveler, and Transitman on the location of the Tampico Short Line, from November, 1903, to June, 1904.

From June, 1904, to August, 1905, Mr. Webber was engaged, as Resident Engineer in charge of 100 km. of reconstruction work, on the Vera Cruz and Pacific Railroad. He then returned to the Mexican Central Railroad as Division Engineer in charge of construction on the Colima Extension, and in April, 1907, was made Assistant Chief

* Memoir prepared by the Secretary from information furnished by Edward Dixon, Esq., General Manager and Engineer, Tampico-Panuca Valley Railway Company, Limited, and from records on file at the Society House.

Engineer, in charge of proposed branch lines and of the Tampico Short Line.

From January, 1908, to August, 1910, he was employed, as Engineer of Betterments and Additions, with the Vera Cruz and Pacific Railroad, and was then made Chief Engineer in charge of the location and construction of branch lines, etc., of that Company.

In August, 1910, Mr. Webber was appointed Principal Engineer of the Construction Department of the Ferrocarril Nacional de Mexico, and was engaged on the construction of the San Andres Tuxtla Branch until 1913, when he became Chief Engineer of Construction for the Tampico-Panuco Valley Railway Company, Limited. He located and constructed the section of this road from Tampico to Panuco, carrying out the work with conspicuous courage and judgment under very difficult political conditions.

During his career of 14 years of railroad work in Mexico, Mr. Webber won a high reputation, both as a clever engineer and as a precise and honorable worker, fair alike to his companies and to his contractors.

He was attacked by smallpox, which was prevalent among his men, and which his duty compelled him to face, and died at Panuco, Ver., Mexico, on January 30th, 1916, within a few days of the projected opening of the road he had completed. His death is deeply mourned by his friends and colleagues and by all who knew his loyal and dependable nature.

Mr. Webber was elected an Associate Member of the American Society of Civil Engineers on October 7th, 1908, and a Member on January 7th, 1913.

FRANK ROBERT WILLIAMSON, M. Am. Soc. C. E.*

Died July 11th, 1915.

Frank Robert Williamson was born in Harford County, Maryland, on December 22d, 1867. In his early boyhood his parents moved to Illinois and settled in Clinton County.

He attended a country school and the graded school in the Village of Huey, and prepared himself for teaching by attending the Normal School at Carbondale.

In the fall of 1887 he entered the University of Illinois, and, after his sophomore year, he taught a country school for a year and then returned to the University, where he completed the course and was graduated in 1892 with the degree of B. S. in Civil Engineering.

* Memoir prepared by Samuel T. Smetters, M. Am. Soc. C. E.

On leaving the University Mr. Williamson entered the employ of the Pittsburgh Bridge Company, and served in both the Pittsburgh and Chicago offices of the Company as Draftsman and Checker.

In 1895 he was in the office of Ralph Modjeski, M. Am. Soc. C. E., in Chicago, where he assisted in designing the draw-span of the Chicago, Rock Island and Pacific Railway across the Mississippi River at Rock Island, Ill.

During 1896 he was employed in the office of the Wisconsin Bridge Company, at Milwaukee, Wis., as Draftsman and Checker.

Mr. Williamson was in the office of the Bridge Division of The Sanitary District of Chicago from 1897 to 1899, where he computed the stresses and designed the sections of eight of the draw-spans over the Main Drainage Channel of the Sanitary District.

He was Assistant Engineer in charge of the drafting-room of the Bridge Department of the Chicago and Northwestern Railway during 1900 and 1901. Under the direction of the Engineer of Bridges, he designed the double-track viaduct across the Des Moines River near Boone, Iowa.

Mr. Williamson was in charge of the drafting-room of the Scherzer Rolling Lift Bridge Company, at Chicago, from 1901 to 1908, and assisted in the design of many important bascule bridges of the rolling lift type. Many improvements in detail and design were due to his skill.

In February, 1908, he again entered the office of The Sanitary District of Chicago, where he continued his work until the time of his death. He assisted in the preparation of the plans for the Eight-Track Bridge across the Main Drainage Channel of the Sanitary District, and was Resident Engineer in charge of the construction of the bridge. His last important work was in connection with the design and construction of the bascule bridge across the Chicago River at Jackson Street. This bridge was not completed at the time of his death.

Mr. Williamson was a man of few words, and was very energetic and determined. He was of uncompromising honesty, and could be trusted with any responsibility he would accept or which he considered his duty, with entire confidence that the interests of his employers would be conserved and the best results obtained.

Mr. Williamson was ever ready to listen with patience and forbearance to the views of others, but was tenacious of his own convictions, and, being gifted with sound judgment, his opinion always commanded respect. His associates and assistants held him in high esteem for his ability and good qualities; he was respected by contractors for his untiring effort to obtain the best work and for his good judgment and timely advice often rendered.

He won the esteem and respect of all who knew him, and always stood for the highest and best interests of the community in which he lived. He was a member of the Normal Park Methodist Episcopal Church.

He is survived by his widow and two sons, Frank Martin and Edwin Paul, aged 14 and 10 years, respectively.

Mr. Williamson was elected a Member of the American Society of Civil Engineers on November 7th, 1906.

LOREN EDWARD HUNT, Assoc. M. Am. Soc. C. E.*

Died January 9th, 1916.

Loren Edward Hunt was born at Austin, Minn., on January 7th, 1870. Three years later his parents moved to Santa Barbara, Cal., where he attended the Grammar and High Schools. On the completion of his primary education, he entered the University of California, and was graduated from the College of Civil Engineering in May, 1893.

From May, 1893, to July, 1895, Mr. Hunt was Assistant Instructor, and from July, 1895, to April, 1902, Instructor, in Civil Engineering at his Alma Mater, and was in charge of the Laboratory for Testing Materials of Construction during the latter period.

In April, 1902, he entered the service of the Bureau of Engineering of San Francisco, Cal., as Assistant City Engineer in charge of the construction of pavements and sewers. He resigned this position in March, 1903, to accept the direction of the Testing Laboratory of the United States Forest Service, at the University of California, which position he held in conjunction with the Chair of Lecturer in Civil Engineering.

In 1909, Mr. Hunt again returned to the office of the City Engineer of San Francisco, and, in 1911, he was made Chief Assistant City Engineer. This position he held at the time of his death, which took place at his home in San Francisco, on January 9th, 1916, after a brief illness.

In his dealings with the general public and with the contractors transacting business with the City Engineer's Office, Mr. Hunt gained a reputation for the most scrupulous fairness, and gave the best of his many talents, energy, and vitality, even at the sacrifice of his personal health, to the service of the City. He never allowed any personal con-

* Memoir prepared by E. F. Haas, H. I. Randall, and M. M. O'Shaughnessy, Members, Am. Soc. C. E., a Committee of the San Francisco Association of Members of the American Society of Civil Engineers.

sideration to conflict with his high sense of public duty, and he was revered as a man as greatly as he was respected as an engineer.

He was a member of the American Society of Testing Materials, the Technical Society of the Pacific Coast, and the Bohemian Club of San Francisco.

Mr. Hunt was elected an Associate Member of the American Society of Civil Engineers on June 3d, 1903.

CURTISS MILLARD, Jun. Am. Soc. C. E.*

Died February 16th, 1916.

Curtiss Millard was born at North Egremont, Mass., on March 23d, 1862. He was graduated from the High School at Great Barrington, Mass., in 1880.

He began his enginering work in August, 1881, as a Chainman, etc., on the New York, West Shore and Buffalo Railway, under Elmer L. Corthell, now President, Am. Soc. C. E., then Chief Engineer of that road. From May, 1884, until May, 1889, he served as Transitman and Assistant Engineer on the New Croton Aqueduct, and from the latter date until August, 1891, he was Engineer for the Contractors for the Bog Brook Dams and the connecting tunnel near Brewster, N. Y. From August, 1891, until March, 1895, Mr. Millard was Roadmaster, Chief Engineer, and Superintendent, successively, of the Charleston, Sumter, and Northern Railroad. From May, 1895, until January, 1896, he was Assistant to the General Freight and Passenger Agent of the Baltimore, Chesapeake and Atlantic Railway, and then, until August, 1896, he was engaged in making examinations and reports relating to water-works and electric lighting plants in Ohio.

In August, 1896, Mr. Millard became Chief Engineer of the St. Louis, Chicago and St. Paul Railway, and from July, 1897, to March, 1900, he was Superintendent of that line. During the last two years of this period he was also Superintendent of the Chicago, Peoria and St. Louis Railway. From March, 1900, until March, 1903, he was General Manager of the Chicago, Peoria, and St. Louis Railway, and from the latter date until February, 1908, President of the Peoria and Pekin Union Railway Company.

About July, 1908, Mr. Millard became Engineer of Maintenance of Way for the Western Division of the Chicago Great Western Railroad, with headquarters at Des Moines, Iowa, which position he retained until January, 1915, when ill health incapacitated him for further work.

* Memoir prepared by the Secretary from information on file at the Society House.

It is evident from this record that Curtiss Millard was endowed with exceptional natural ability, since, with only a High School education, he was able to take on responsibilities of a high order. He was devoted to his work, and faithful in its execution. These qualities, combined with a sterling character, made him successful and useful as a man, as an engineer, and as a railroad official.

Mr. Millard was married in 1890 to Miss Caroline Radford, at Yonkers, N. Y. He is survived by his widow and two of his three children.

Mr. Millard was elected a Junior of the American Society of Civil Engineers on April 3d, 1889.

PAPERS IN THIS NUMBER

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PAPERS AND DISCUSSIONS CURRENT IN PROCEEDINGS

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William P. Morse

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

VOL. XLII—No. 5

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May, 1916

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OF

CIVIL ENGINEERS

(INSTITUTED 1852)

VOL. XLII—No. 5

MAY, 1916

Edited by the Secretary, under the direction of the Committee on Publications.

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CLEMENS HERSCHEL

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The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

TELEPHONE NUMBER........................1446 Circle.
CABLE ADDRESS......................."Ceas, New York."

Vol. XLII. MAY, 1916. No. 5

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PROCEEDINGS

SOCIETY AFFAIRS

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MINUTES OF MEETINGS

OF THE SOCIETY

April 19th, 1916.—The meeting was called to order at 8.30 P. M.; Vice-President Clemens Herschel in the chair; Chas. Warren Hunt, Secretary; and present, also, 120 members and 15 guests.

A paper by James B. Hays, Jun. Am. Soc. C. E., entitled "Designing an Earth Dam Having a Gravel Foundation, with the Results Obtained in Tests on a Model," was presented by title, and discussed by Edward Wegmann, M. Am. Soc. C. E. Written discussions on this paper by Messrs. W. G. Bligh, J. C. Oakes, C. E. Grunsky, H. T. Pease, and Malcolm Elliott, were presented by title.

The following subject was taken up for informal discussion:

"What relations should exist between the National Engineering Societies and the local sections or associations of their members, and, in the interests of the Profession, what should be the attitude of both of the above to other local engineering societies or clubs?"

Mr. Hunt opened the discussion from the standpoint of the American Society of Civil Engineers, and read a communication on the subject from the President, Dr. Elmer L. Corthell.

The subject was discussed by Paul M. Lincoln, Past-President, Am. Inst. Elec. Engrs., D. S. Jacobus, President, Am. Soc. Mech. Engrs., W. L. Saunders, Past-President, Am. Inst. Min. Engrs., C. D. Marx, and George F. Swain, Past-Presidents, Am. Soc. Civ. Engrs., and by Messrs. John F. Coleman, F. G. Jonah, D. Bontecou, H. S. Crocker, and John Bogart.

On motion, duly seconded, it was ordered that the report of the discussion on the relations existing between National Engineering Societies and local associations of their members, etc., be printed in full in *Proceedings*.*

The Secretary presented the report of the Tellers appointed to canvass the ballot on the following questions relating to the proposed revision of the Constitution:

"No. 1—Shall membership in the Society be open to women as well as men?

"No. 2—The Board of Direction now elects members in all grades. Shall it also have power to expel and discipline?

"No. 3—Shall the duties of a Professor of Engineering in a technical school be considered as equivalent to responsible charge of engineering work? (At present such duties are only counted as active practice.)

"No. 4—Is it desirable that the Society should adopt some form of District Organizations along lines advocated by the Meeting of the Presidents of the Local Associations at the time of the Annual Meeting of 1915?

"No. 5—Shall persons who are engaged in the promotion, manufacture, or sale of proprietary or patented articles used in engineering work

(a) Be admitted to the Society?

(b) If so, shall they be placed in a class by themselves?

"No. 6—Shall the present requirements for admission to the highest grade of Corporate Membership be increased?"

"New York, N. Y.
April 15th, 1916.

"To the Board of Direction,
"American Society of Civil Engineers:

"The Tellers appointed to canvass the Ballot on the Proposed Revision of the Constitution report as follows:

"Total number of Ballots received...........		3 219
"Ballots from members in arrears of dues...	25	
" with illegible signatures...........	4	
" unsigned	21	
" stamped, not signed..............	10	60
Ballots to be counted..................		3 159

* See pp. 317–343.

"Question No. 1	Yes	1 352	No	1 746	Total	3 099	Majority	against	394
" " 2	"	2 650	"	434	"	3 084	"	in favor	2 216
" " 3	"	1 283	"	1 804	"	3 087	"	against	521
" " 4	"	2 414	"	432	"	2 846	"	in favor	1 982
" " 5(a)	"	1 042	"	1 926	"	2 968	"	against	884
" " 5(b)	"	1 282	"	470	"	1 752	"	in favor	812
" " 6	"	1 455	"	1 478	"	2 933	"	against	23

"Respectfully submitted,

"ARTHUR S. TUTTLE,
"LINCOLN BUSH,
"CHAS. WARREN HUNT,
"Tellers."

The Secretary announced the election of the following candidates on April 18th, 1916:

AS MEMBERS

HENRY GIRDLESTONE ACRES, Toronto, Ont., Canada
HOMER GAGE BALCOM, New York City
LEWIS WARRINGTON BALDWIN, Savannah, Ga.
WILLIAM HENRY BRENTON, San Francisco, Cal.
OLIVER WESTON CONNET, Baltimore, Md.
JENKS BUFFUM JENKINS, Baltimore, Md.
WILLIAM WARREN ORCUTT, Los Angeles, Cal.
WILLIAM ROBERT POWRIE, Minneapolis, Minn.
ROBERT MALCOLM WATSON, Rutherford, N. J.
EDMUND LEE ZEARLEY, Uniontown, Pa.

AS ASSOCIATE MEMBERS

WALTER RUSSELL ABBOTT, Seneca Falls, N. Y.
STANLEY EDWARDS BATES, Chicago, Ill.
WALTER SAMUEL BAVER, Johnstown, Pa.
THOMAS BERNARD BERGAN, Auburn, N. Y.
FRED MERRITT BILLINGS, San Diego, Cal.
JAMES ALANSON CHILDS, St. Paul, Minn.
JOHN JOSEPH COX, Ann Arbor, Mich.
HARDY CROSS, Providence, R. I.
JOSEPH AUGUSTINE FAHY, Pensacola, Fla.
LEE FRASER, New York City
FRED FORAKER FRIEND, Mercedes, Tex.
RIDGWAY MILLS GILLIS, Kalama, Wash.
FRANK STICKNEY GREELY, Seattle, Wash.
WILLIAM GARRETT GROVE, New York City
FREDERICK ALBERT HOLSTMAN, Chicago, Ill.
JOHN RUDOLPH IAKISCH, Powell, Wyo.
HENRY KERCHER, Cleveland, Ohio
JAMES IRWIN KUHN, Pittsburgh, Pa.

Walt Ferd Lehfelt, Milwaukee, Wis.
George Abraham McClellan, Bonham, Tex.
Harry Ash Pearce, Ancon, Canal Zone, Panama
Willard Fred Pond, Rochester, N. Y.
Bernhard Rasmussen, La Vega, Dominican Republic
Ward Hall Ream, New York City
Harry Calvin Reeder, San Francisco, Cal.
William Hatfield Sears, Chattanooga, Tenn.
Arthur Lassell Shaw, Fall River, Mass.
Everett Clerc Smith, Jr., Ambridge, Pa.
Somers Hanson Smith, Chicago, Ill.
Philip Frederick Stephens, Rochester, N. Y.
James Lawrence Thayer, Davenport, Wash.
Herbert Herman Tracy, Norfolk, Nebr.
Albert Matthias Wolf, Melrose Park, Ill.
Rene Barber Wright, Portland, Ore.

As Juniors

José Villes Bagtas, Atimonan, Philippine Islands
Claude Gilbert Benham, Norfolk, Va.
Sidney Breese Bowne, Mineola, N. Y.
Frederick Augustus William Davis, New York City
Guillermo de la Guardia, New York City
Edward James Dougherty, South Baltimore, Md.
Hezekiah Shailer Dow, New York City
Lawrence Scofield Holmboe, Oklahoma City, Okla.
Alexander Matthews McKean, Providence, R. I.
Ralph Richardson Marrian, Watertown, N. Y.
John Siemon Means, Denver, Colo.
Selby Quattlebaum, Roanoke, Va.
Erich Ernest Frederick Schmied, New York City
Herschel C. Smith, Norman, Okla.
Richard Laurence Templin, Champaign, Ill.
Frank Lloyd Weaver, Baltimore, Md.
Claude Allen Webb, New York City

The Secretary announced the transfer of the following candidates on April 18th and 19th, 1916:

From Associate Member to Member

Hunley Abbott, New York City
Melvin David Casler, Mount Vernon, N. Y.
Paul August Hartung, Kansas City, Mo.
Frank Cecil Magruder, Scottsbluff, Nebr.
Harry Lincoln Noyes, Niagara Falls, N. Y.
Frank Harold Shaw, Lancaster, Pa.

ROGER WOLCOTT TOLL, Denver, Colo.
HOWARD PLATT TREADWAY, Kansas City, Mo.
ALEXANDER PIRIE YOUNG, Topeka, Kans.

FROM JUNIOR TO ASSOCIATE MEMBER

ARTHUR POPE ACKERMAN, Cornwall-on-Hudson, N. Y.
HOWARD FRED BELL, Cody, Wyo.
ROBERT HAMMOND BOYNTON, Frankfort, Ind.
GRAHAM BERNARD BRIGHT, Blacksburg, Va.
WILLIAM ELIJAH BUELL, JR., Montreal, Que., Canada
JOHN CLAUSNITZER, New York City
CHARLES LOUIS DIMMLER, Berkeley, Cal.
WILLIAM FREDERICK FOX, New York City
HENRY COLLINS HITT, Tacoma, Wash.
RIDGELY CASEY LILLY, Vicksburg, Miss.
DONALD HEBARD MAXWELL, Chicago, Ill.
EDWARD HARPER PRENTICE, Amsterdam, N. Y.
HERMAN FRED SCHOLTZ, Seattle, Wash.
GEORGE CARTER STONE, Boston, Mass.
HOWARD THOMAS WARE, El Paso, Tex.
WILLIAM WEST WILSON, Washington, D. C.
LAWRENCE LEWIS WINANS, Austin, Tex.

The Secretary announced the following deaths:

FREDERICK WILLIAM DOANE HOLBROOK, of Seattle, Wash., elected Member, October 6th, 1886; died April 13th, 1916.

FRANS ENGSTRÖM, of Pittsburgh, Pa., elected Associate Member, May 4th, 1892; died March 20th, 1916.

Adjourned.

May 3d, 1916.—The meeting was called to order at 8.30 P. M.; V. H. Hewes, M. Am. Soc. C. E., in the chair; Chas. Warren Hunt, Secretary; and present, also, 88 members and 11 guests.

The minutes of the meetings of March 15th and April 5th, 1916, were approved as printed in *Proceedings* for April, 1916.

A paper by H. H. Wolff, M. Am. Soc. C. E., entitled "The Design of a Drift Barrier Across White River, near Auburn, Washington", was presented by the author and illustrated with lantern slides.

The Secretary announced the following deaths:

HENRY COATHUPE MAIS, of Melbourne, Victoria, Australia, elected Member, June 6th, 1883; died February 25th, 1916.

WILLIAM RIDLEY NEELY, of Portsmouth, Va., Elected Member, July 9th, 1906; died April 11th, 1916.

CHARLES HENRY PRESTON, of Norwich, Conn., elected Member, October 5th, 1909; died April 20th, 1916.

Adjourned.

OF THE BOARD OF DIRECTION

(Abstract)

April 18th, 1916.—The Board met at 10 A. M.; Vice-President Herschel in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Bontecou, Bush, Clapp, Coleman, Craven, Crocker, Davies, Duryea, Endicott, Fuller, Haskell, Hawley, Humphreys, Jonah, Keefer. Khuen, McDonald, Marx, Montfort, Ricketts, Swain, and Tuttle.

A communication from the Seattle Association of Members on matters connected with the Weather Bureau was reported upon by a Committee consisting of Messrs. Hedges, Crocker, and Marx, as follows:

"The Committee to which was referred the question of extending the functions of the weather service, especially in the middle and far western States so that precipitation records be taken at additional points and especially at higher elevations on the various drainage areas, recommends that the Board of Direction of the American Society of Civil Engineers petition the Weather Bureau to extend its service, and pledges its support to a measure to be introduced by the Weather Bureau in Congress to this effect, and through the proper channels."

The recommendation of the above Report was adopted.

Various appropriations were made for the expenses of Special Committees.

The rules now in force regarding admission requirements were rescinded, and new rules were substituted.*

The paying off of the balance of the mortgage ($40 000) by the sale of certain securities held in the Reserve Fund was reported, the property of the Society now standing free and clear.

The appointment of Messrs. Fred Lavis, Chandler Davis, B. F. Cresson, Jr., P. W. Henry, and Edgar Marburg, as representatives of this Society on the Joint Pan-American Engineering Committee was reported.

The following resolution was adopted:

"WHEREAS: the Board of Direction has received from the Philadelphia Association of Members of the American Society of Civil Engineers the formal charge that John A. Ockerson of St. Louis, a Member of this Society, in a circular widely circulated by him among members of this Society, made certain inaccurate and incorrect statements, among them the following, namely:

> "'An invitation has been extended to the American Society of Civil Engineers to enter 'the United Engineering Society as an additional Founder Society.' This invitation itself shows that the destinies of the 'Founder Societies' is largely if not wholly controlled by a superior authority, and the fact must not be overlooked that the relationship which exists between the United Engineering Society and the Founder Society which

* See page 344.

gives the former authority over them, has not been presented in detail to our members.

" 'Suppose we become an 'additional Founder Society', and desire to put before the public a measure which we have conceived and which we deem important. It must have the sanction of the United Engineering Society, representing a majority of the Founder Societies, which can prevent action, or, if approved, the United Engineering Society would stand before the public as the sponsor of the measure. This illustration applies equally to all of the Founder Societies;' "

"NOW THEREFORE: Voted:—that there is nothing in the Constitution or management of the United Engineering Society to warrant the assertions above quoted. The United Engineering Society is the equivalent of a Board of Trustees created by the three Founder Societies occupying the 39th Street Building, of which this Society has been invited to become a fourth, and was created and is carried on for business purposes connected with the management of the real property and libraries of the Founder Societies.

"VOTED FURTHER: that a copy of these resolutions be sent by the Secretary to the Secretaries of each of the local Associations of Members of this Society."

The following resolutions with relation to the Joint Conference Committee of Engineering Societies were adopted:

"RESOLVED: That the Joint Conference Committee of Engineering Societies be increased by the addition of one member from each of the five constituent societies, so that each will be represented by three members."

"RESOLVED: That the Joint Conference Committee of Engineering Societies shall have authority to take action on all general or public matters relating to the welfare of the Profession, and in connection with which joint action seems desirable; on the condition that the Joint Conference Committee records in its minutes any action taken and reports such action for approval at the next subsequent meeting of the governing bodies of each of the constituent societies."

Action was taken on members in arrears for dues.

The resignations of 2 Members, 3 Associate Members, and 4 Juniors, were accepted.

Adjourned.

April 19th, 1916.—The Board met at 5 P. M.; Vice-President Herschel in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Bogue, Bontecou, Bush, Clapp, Coleman, Craven, Crocker, Davies, Duryea, Endicott, Fuller, Greiner, Harwood, Haskell, Hawley, Humphreys, Jonah, Keefer, Khuen, McDonald, Marx, Montfort, Swain, and Tuttle.

The following resolutions were adopted:

"RESOLVED: That it is the sense of this Board that the railroads of this country are indispensable to its defence.

"RESOLVED: That any movement having in view the National defence should embrace among other things the following essentials:

"(A) The selection by the Government in advance of such trunk lines, or groups of lines, as will best serve for the transportation of troops, munitions, and sustenance under all probable theories of points of attack.

"(B) The determination in advance of the compensation to be paid the railroads for transportation of troops, munitions, and supplies.

"(C) The collection by the National Government of full information as to the capacities of the railroads of the country to meet military emergencies.

"(D) The training of Government and railway officers and employees for thorough co-operation in all matters connected with military transportation.

"(E) The establishment of facilities for, and the removal of obstacles to, the prompt movement of troops, munitions, and supplies, over the railroads of the country.

"RESOLVED: That a copy of this resolution be forwarded to the Secretary of War and the American Railway Association, and the Subcommittee of the Naval Advisory Board in charge of gathering information in the interest of Preparedness."

A report from the Membership Committee, which had been in session since 10 A. M., was received and acted upon.

Ballots for membership were canvassed, resulting in the election of 10 Members, 34 Associate Members, 17 Juniors, and the transfer of 17 Juniors to the grade of Associate Member.

Nine Associate Members were transferred to the grade of Member. Applications were considered and other routine business transacted.

Adjourned.

REPORT IN FULL OF AN INFORMAL DISCUSSION AT THE HOUSE OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS, ON THE EVENING OF APRIL 19th, 1916, ON THE SUBJECT:

"What relations should exist between the National Engineering Societies and the local sections or associations of their members, and, in the interests of the Profession, what should be the attitude of both of the above to other local engineering societies or clubs?"

April 19th, 1916.—The meeting was called to order at 8.30 P. M.; Vice-President Clemens Herschel in the chair; Chas. Warren Hunt, Secretary; and present, also, 120 members and 15 guests.

THE CHAIRMAN.—The meeting will now take up the discussion of the question: "What relations should exist between the National Engineering Societies and the local sections or associations of their members, and, in the interests of the Profession, what should be the attitude of both of the above to other local engineering societies or clubs?" You will see that it is a very broad subject. The Secretary has some ideas which he will present.

CHAS. WARREN HUNT, SECRETARY, AM. SOC. C. E.—Mr. Chairman, this subject was proposed for discussion this evening because it is very important. With your permission, I will make a brief statement in reference to the formation of the local associations of the American Society of Civil Engineers.

The formation of some kind of local associations of members had been discussed casually for a number of years, but no definite suggestions were made until the early part of 1905. For some months before that time the Board of Direction had been discussing the matter, and this discussion resulted in the sending out on March 7th, 1905, of a circular-note embodying the views of the Board to at least three specially selected members of the Society in Albany and Troy, Boston, Cleveland, Chicago, Detroit, Kansas City, Mexico City, New Orleans, Philadelphia, Pittsburgh, St. Louis, St. Paul and Minneapolis, San Francisco, and Washington. The whole subject was taken up for discussion at the Cleveland Convention, in June, 1905. The views of the Board of Direction and the circular sent out were as follows:*

"VIEWS OF THE BOARD OF DIRECTION AS TO THE FORMATION OF LOCAL ASSOCIATIONS OF MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS, MARCH, 1905.

"The proposed formation of a Local Association of the Membership of the Society in Washington, D. C., has led the Board to a careful consideration of the desirability of such Associations in all localities in which the membership available for such purpose is sufficient in number.

"The subject of the formation of local chapters of the Society was considered a number of years ago, but nothing was accomplished in this

* *Proceedings*, Am. Soc. C. E., for August, 1905, pp. 273-274.

direction, as there developed considerable opposition to the formation of such chapters.

"The present suggestion is understood to have a somewhat different end in view, *viz.,* the formation of local associations of our members for professional and social intercourse only. Similar propositions have been considered somewhat informally by the Board of Direction heretofore, one emanating from members residing in the City of Mexico, and another from St. Louis, although the latter proposition was merely the decision of the question as to whether the present local engineering society of St. Louis could be furnished, upon request, with certain of the Society publications, and allowed to discuss them with the privilege of having such discussion, if valuable, published by the Society. This latter question was decided by the Board in the affirmative, but nothing further has been heard from our members in that city.

"The Board recommends that, wherever possible, steps be taken calling the attention of the membership to this matter, and that such Associations be formed.

"In making this recommendation, the Board wishes to point out that associations of this character would be of great advantage to the Profession in general, and would widen greatly the influence of this Society, and enhance its standing in the various communities; that if coincidentally (or practically so) the papers issued in our *Proceedings* could be brought up for discussion at meetings in various localities and the resulting discussion forwarded to the Secretary of the Society for publication, subject to the rules in force in regard to the discussions which now take place in New York, it would result in great advantage to the *Transactions,* and that, in nearly all cases, it would be possible for the author of a paper published by the Society to be within reasonable traveling distance of some point at which his paper is to be read, and give him an opportunity to present it in person.

"It is further believed that if this project can be carried out successfully, it would bring non-resident members into closer touch with all the work of the Society, and place the non-resident member practically in the position of a resident member of the Society in the particular locality in which he lives.

"It is further submitted that the advantages to engineers who are not now members of the Society would be very great, and that the formation of such an association in any city would not interfere in any way with existing local engineering societies or clubs.

"The Board has prepared a draft of proposed By-Laws for such an association (copy enclosed herewith), which, in its opinion, would be satisfactory.

"Referring to this draft, it is believed that the following Articles: No. 1, relating to the Name, Location and Object; No. 2, relating to Membership, and No. 6, relating to Amendments, should in substance be incorporated in the By-Laws of all such associations, but that Article No. 3, relating to Dues; No. 4, relating to Officers, and No. 5, relating to Meetings, may all be varied in detail according to special local requirements or convenience.

"These are inserted in the draft as suggestions for consideration in each special case, although it would be well if, in all matters except the amount of dues, all such associations had exactly similar By-Laws.

"In this connection it should be noted that the Resident Membership of the Society pays an additional fee of $10 per annum for the special privileges of such membership, and that a much less yearly sum would probably suffice for the dues in Local Associations as outlined herein.

"By order of the Board of Direction.

"CHAS. WARREN HUNT,

"*Secretary.*"

Enclosed with this was a proposed form of Constitution for Local Associations, composed of 6 articles covering name, location, and object, membership, dues, officers, meetings, and amendments. The important things were: The objects, which were stated to be "advancement of engineering knowledge and practice, the maintenance of a high professional standing among its members, and the furtherance of the general welfare of the American Society of Civil Engineers".

"Among the means to be employed for these purposes shall be: Meetings for the presentation and discussion of professional papers, particularly those issued by the American Society of Civil Engineers, and the encouragement of engineers who are not members to attend and take part in the professional and social features of such meetings."

Under the head of Membership: "The membership of this Association shall be restricted to persons who are members of the American Society of Civil Engineers in any grade and who reside within........ miles of............................. All such may become members of this Association without payment of Entrance Fee, but should the membership in the American Society of Civil Engineers of any person cease from any cause, he shall at the same time cease to be a member of this Association."

Under the head of Meetings: "At these meetings the business of the Association shall be transacted, and the discussion of professional papers published by the American Society of Civil Engineers, or specially prepared for the occasion, shall be in order. Such discussions may be furnished to the Secretary of the American Society of Civil Engineers for publication, subject to the approval of the Publication Committee of that Society."

Under the head of Amendments: "This Constitution may be amended only by a two-thirds vote of all members of the Association, which vote may be taken, if necessary, by letter-ballot, provided such amendment shall have previously received the approval of the Board of Direction of the American Society of Civil Engineers."

The important clauses, which every Association now in existence has adopted, are the statement of the Objects of the Association, the Restriction in Membership, and the clause covering proposed Amendments. All other matters, such as number of officers, dues, number of meetings, and in short everything which should be decided locally, are different in the various Associations.

At the discussion at the Cleveland Convention a great deal of opposition to the proposed movement developed. In Pittsburgh a vote was taken by which it appeared that those in favor of the formation of a Local Association in that city were 14, while those who opposed it numbered 42.

In Washington, where the movement started, no decision was reached at that time. In Cleveland the reports indicated that favorable action might be expected. In Boston it was stated to be the unanimous opinion of those who had been consulted that it would be difficult to arouse sufficient enthusiasm to have such an organization. In St. Louis a meeting of members held March 24th, 1905, adopted a resolution to the effect that it was not desirable at that time to have such an organization in St. Louis.

In Philadelphia and Chicago it was evident that there was no possibility of accomplishing anything.

At all events, it seems to be of interest to state that, of the 15 Associations now in existence, there are only 5 in the cities selected by the Board at that time; *viz.*, San Francisco, Cleveland, Philadelphia, New Orleans, and St. Louis, and that there are now flourishing Associations in Denver, Atlanta, Seattle, Portland, Ore., Los Angeles, Texas, Spokane, Baltimore, and San Diego, Cal.

Doubtless the increase in total membership of the Society from 3 249 in 1905 to 7 879 in 1916—143% in 11 years—has had much to do with making these Associations possible. It also will be noticed that the advisability, or even necessity, for such Associations seems to increase with the distance from headquarters, as there are 6 Associations in 3 States, California, Oregon, and Washington, and only one each in Colorado, Missouri, Texas, Louisiana, and Georgia.

The objections that were made in various localities were almost all based on the probable effect that the formation of such Associations of this Society would have on already existing Local Engineering Societies or Clubs. A committee of members in Chicago summed up the objections, stating:

"The local engineering societies as they exist seem to satisfy local needs. They are generally organized along the same lines and the plan followed may reasonably be assumed to fit the requirements. They manage their own affairs, and this satisfies the desire for a fair degree of independence usually felt. A chapter, on the other hand, would suffer from its lack of independence. Sectional jealousies might become aroused and impair the allegiance to the parent Society and the good feeling which now so happily exist."

The speaker remembers very well trying by word of mouth and by correspondence to point out that, if properly handled, such Associations would be a benefit rather than a detriment to existing Local Societies or clubs, the general line of argument being as follows:

1. Members of this Society are almost universally members of any local Engineers' Club.

2. The difficulty in keeping up interest in local meetings lies largely in the fact that professional papers cannot be published in advance of their presentation for discussion, and sometimes they are not published at all, and Engineers will not go to the trouble and expense of preparing papers unless there is a good prospect of publicity and valuable discussion.

3. That by using the papers published by the Society in *Proceedings* for discussion at meetings held under the auspices of the Local Association in the rooms of the local club, and inviting members of the latter to attend and take part, interest would be stimulated, and the local club strengthened.

These, and similar arguments, did not seem to be of much avail, and in only three places Local Associations were formed during 1905, Kansas City (April 8th) San Francisco (April 28th), and Memphis (October 10th). The Kansas City and Memphis Associations may still be alive, but practically nothing has been heard from them since the date of their organization. The San Francisco Association, on the contrary, has been very successful and very useful, as is evidenced by its increasing membership, financial condition, and the work it has done.

The next Association formed was the Colorado Association, with headquarters in Denver. The date of its organization was December, 1908. The Atlanta, Ga., Association was organized on March 14th, 1912. Five Associations were formed during 1913: Philadelphia, Seattle, Portland, Ore., Southern California (Los Angeles), and Texas; five in 1914, Spokane, Louisiana (New Orleans), Baltimore, St. Louis, Northwestern (Minneapolis), and two in 1915, Cleveland and San Diego, Cal.

At the Annual Meeting of January, 1915, a Conference of the Presidents of these Associations was held, and recommendations were made that the membership of the Society be divided geographically into Districts; every member of the Society residing in the territory covered by that District to become a member of the District Organization without payment of further dues. Each District to have a President or Chairman, and a Secretary, and existing Local Associations in that District to become Local Sections reporting to the management of the Society through the District Organization; each District to elect its own representative on the Board of Direction of the Society.

A Committee of the Board of Direction appointed to prepare a revised Constitution of the Society decided to place certain fundamental questions before the membership for its opinion before drawing up the Constitution, and one of the questions was:

"Is it desirable that the Society should adopt some form of District Organizations along lines advocated by the Meeting of the Presidents of the Local Associations at the time of the Annual Meeting of 1915?"

Out of the total vote of more than 3 100 Corporate Members of the Society the majority in favor of District Organizations on the lines suggested by the Presidents of the Local Associations was 85 per cent.

It is evident that the Local-Association idea, and probably the General-District idea, has come to stay, so far as this Society is concerned, and this question has been brought to the attention of this Meeting for the purpose of securing the assistance of representatives of the other National Societies in an attempt to find out what the difficulties have been, and what general relations should be established with each other by all these Local Associations, and in the hope of securing some basis for co-operation between all Local Engineering Associations, whether members of the National Societies or non-members, which will result in benefit to the Profession in general.

Mr. Chairman, the President of this Society, Dr. Elmer L. Corthell, is unfortunately prevented from being present this evening, much to his regret. He is in the country, and quite ill, but from his sick bed he dictated the following for presentation here as his suggestions for a plan:

Elmer L. Corthell, President, Am. Soc. C. E. (by letter).—In this carefully considered outline plan, the objects kept in view are the *Solidarity* of the Engineering Profession in the United States and the *Independence* of its individual Society Units.

Elements.

A.—"*Joint National Conference Committee*" of the five National Engineering Societies—Civil, Mechanical, Electrical, Mining, and Marine Engineering and Naval Architecture,

B.—"*Joint Local Conference Committees*" of the Associations or Chapters of the Societies above named located at population centers of the country (including members in districted areas) constituting a connecting "live wire" with the

C.—*Local Engineering Societies.*

Scope and Duties of Each Element.

1st.—(A) (Joint National Conference Committee) will embrace all general and National Engineering subjects, problems, and policies, transmitting to (C) (Local Engineering Societies), through (B) (Joint Local Conference Committees) information, and receiving from (C) through the same channel their desires and suggestions.

2d.—The National Societies, through their Joint Local Conference Committees, will encourage their members to apply for membership in the Local Engineering Societies, and the latter will, through the Joint Local Conference Committees, encourage their members, on the other hand, to apply for admission in the National Societies—and all Societies through the same channel will urge engineers not now members of any Society (the number being considerable) to apply for membership in *some* Society—with the view to consummating effectively the solidarity of the entire Profession, numbering it is estimated more than 60 000.

3d.—*Technical Literature.*—Papers of general, National or international interest to be, generally, presented to the National Societies; but those of Local, Municipal, and State interest to be presented to the Local Engineering Societies—as the former demand a National distribution and the latter a local circulation.

4th.—All Societies—National and Local—through the intermediary of the Joint National Conference Committee and the Joint Local Conference Committees, to work for the promotion, protection, and advantage of every one of its 60 000 members—from the National, State, Municipal, and individual point of view—in matters of legislation—National, State and Municipal—in civic and patriotic measures—in employment of the Engineer and in the publicity necessary and proper to bring to the notice and appreciation of the public at large—and the National, State, and Municipal Governments, the duty, ability, and determination of the Engineer to assert and assume his rightful place in the body politic as a useful, interested and patriotic citizen.

5th.—The plan above outlined, if carried into full and effective execution, will redound to the public welfare and to the general and personal advantage of the Engineer, and it will soon prove to the Nation that his fundamental purpose is not altogether to "make a living, but to live a life" of high endeavor and usefulness, and with the motto *"Service and Self Sacrifice"*.

The Chairman.—We have with us this evening members of the other three National Engineering Societies, the American Institute of Mining Engineers, the American Institute of Electrical Engineers, and the American Society of Mechanical Engineers, which Societies have had considerable experience in the formation and working of local associations and sections. I will call on Paul M. Lincoln, Past-President of the American Institute of Electrical Engineers, kindly to open the discussion.

Paul M. Lincoln, Past-President, Am. Inst. Elec. Engrs.—Mr. President and gentlemen of the American Society of Civil Engineers, the question before you to-night is a general one as to the relations which should exist between the National Engineering Societies and their branches or sections in various localities throughout the country.

I believe this is a question which each of the National Societies must study in its own way, for its own particular conditions. For my part, I can simply enlighten you to some extent concerning the experience of the American Institute of Electrical Engineers on this question, and that will be useful to your Society only in so far as you may find application for it; I do not advance these ideas as necessarily a general answer.

Now, let me call your attention for a moment to the history of the sections' movement in the American Institute of Electrical Engineers. That movement started with Past-President Charles F. Scott, who was elected President in 1892. At the time of Mr. Scott's election to that office, he and I were close neighbors and I had the privilege of hearing him go over this matter and express his ideas, his ideals, the things that he wished to accomplish during his presidency of the Institute, and this matter of sections of the Institute was one that was close to his heart at that time.

His reasoning concerning sections was about like this: He asked, what is our Institute to our membership? To most of them, particularly those who live at a considerable distance from headquarters, the Institute is an impersonal thing. It simply sends to its members its *Transactions* once a month, and possibly one or two other communications during the course of the year; and once a year a ballot; and that is about all the membership gets. It is an impersonal thing. It is not personal.

Now Mr. Scott's reasoning was, that in order to make our Institute of the utmost value to the membership, we must make it more than something impersonal. We must make it personal. We must bring the Institute to the men. The physical dimensions of our country make it impossible for those living in San Francisco and Chicago and other distant cities to take any active personal interest in the affairs of the American Institute of Electrical Engineers. Now, he said, "the answer to that is to form sections of our Institute in these various localities", and that was one of his first moves when he became President. I recall very distinctly that Mr. Calvin W. Rice, whom I notice in the audience here this evening, was appointed by Mr. Scott as the first Chairman of the Sections' Committee of the American Institute of Electrical Engineers, back in 1902, 14 years ago.

So that it is to Past-President Scott and his vision that the American Institute of Electrical Engineers owes what has been accomplished in the matter of sections; to him at least it owes its inception. Now, just a word as to my own connection with that movement. It happened that I was residing in Pittsburgh at that time, and it also happened that I became the first Chairman of the Pittsburgh Section of the American Institute of Electrical Engineers. A number of years afterward—in 1909, if I remember correctly—I was appointed as Chairman of the Sections Committee, following Mr. Rice, or following, possibly, Mr. Rice's successor, and held that office for some five years, if I remember correctly. During this five years, therefore, I was thrown into very close contact with the conduct of the sections movement in the American Institute of Electrical Engineers. And now, let us come down to the present status of their local sections: First, the constitutional provisions: What are they? Well, as we see it in the American Institute of Electrical Engineers, the first requisite in the Constitution is to allow the local sections a maximum of autonomy, to place as few restrictions on them from headquarters as possible.

Let me read in part the Articles of the Constitution which make provision for these local sections. It says: "The officers of each section shall consist of a chairman, a secretary, and such other officers as each section may find desirable." That, as you see, gives a maximum of autonomy in this respect. "These officers shall be elected by the votes of the Fellows, Members, and Associates of that Section, in the manner provided in the Section By-laws. The election of any Fellow, Member, or Associate as a Section officer, shall not debar him from election or appointment to any other office in the Institute."

The object of the Constitution, therefore, is to place just as few restrictions on the activities of these sections as possible, and still retain their loyalty to the Institute; and, in that particular, I believe we have been very successful.

The number of members required to form a section is not fixed by the Constitution, but by the By-Laws. One of these By-Laws prescribes that a petition for the formation of a section "shall specify the territory to be included, and shall be signed by not less than 25 members residing therein"; that is to say, if 25 members in any given locality get together, they may request the formation of a section. That the section will be formed on the request of 25 members does not follow, that lying within the province of the Board of Directors; but 25 members may initiate such a movement; and, up to date, I think I am correct in saying that no request for the formation of a section coming from 25 members or more, has been refused.

At the present time we have 32 of these sections, including one which has just been authorized in Kansas City, Mo. These 32 sections are distributed geographically all the way from Panama and Mexico on the south to Vancouver and Toronto on the north; from San Francisco, Portland, Los Angeles, and Seattle on the west, to Boston, Baltimore, Washington, and Atlanta on the east.

Just a word about the expenses. How do we look after the expenses of these sections' meetings? The parent body, the American Institute of Electrical Engineers, appropriates money to a certain extent for the sections' meetings. The amount to be appropriated is fixed by the by-laws. Perhaps you will be interested in knowing just how that is taken care of. Let me quote from the by-laws:

"It shall be the duty of the Secretary of the Section to send to the chairman of the Sections Committee, on or before October 1st of each year, an estimate of the appropriations required from the Institute for the expenses of the Section during the year ending the 30th of the following September.

"Each Section shall conduct its affairs in such a manner as to demand for its maintenance a minimum of financial support by the Institute consistent with the activities carried on by that Section. Excepting upon the request of a Section stating specific reasons therefor, and special action thereon by the Sections Committee, the appropriation of Institute funds during any fiscal year for the meeting expenses of any Section shall not exceed in the aggregate a sum to be determined as follows:

"a. One hundred dollars for each Section, independently of the number of members in that Section.

"b. One dollar and a quarter for each Institute member who shall reside within the territory of each Section at the beginning of the administrative year."

In addition to these two items for the expenses of the Sections, they are allowed to have what are known as local memberships, that is, they may admit local members within the limits of the local sections, charging the members an amount which varies usually one or two dollars a year. Some of the sections, particularly in Schenectady and Lynn, take advantage of that particular feature to a very considerable extent.

There is one other provision, in the American Institute of Electrical Engineers, which I think is of tremendous benefit in keeping this section movement in a healthy condition, and that is the provision in the Constitution for the payment of the traveling expenses of a delegate from each Section to the Annual Convention, which occurs usually in the latter part of June. This insures a full attendance of Section representatives at the Annual Convention and there they have official standing as Section delegates. They talk over their affairs, and have enthusiastic meetings. That, I believe, is one of the main forces back of the Section movement in the American Institute of Electrical Engineers, the fact that the traveling expenses of the Section delegates are reimbursed by the Institute. It induces a rather full attendance at these Section meetings, and has had a very good effect on them. I will give you a little more on that line later.

There is another point on which we should lay stress here to-night, and on which we have labored considerably in the local Sections of the American Institute of Electrical Engineers, and that is the matter of co-operation between the local Sections of our Institute and the other engineering bodies in those localities. It is a matter which has been talked over to a very considerable extent, and we have a large amount of experience on it. I am going to dwell on that point for a few moments. It has always been my endeavor and aim, so far as I have been able to guide the Sections, to insist that the spirit behind the relations between the local Sections of the American Institute of

Electrical Engineers and the other engineering bodies in any locality, shall be one of co-operation rather than antagonism.

Antagonism will never get us anywhere, whereas co-operation is the thing for which we are all striving; so it has always been my endeavor to work for that co-operation. It has also been my feeling that there was no cast-iron way of bringing about co-operation in any local Section, that the methods of bringing about that co-operation were necessarily local problems, and had to be worked out in each locality for itself.

This question of the methods of bringing about co-operation has been a matter of debate in the Sections to a considerable extent, and I am just going to read to you some of the reports of the Sections delegates at our Sections meeting. These reports are printed each year, and I have here, for instance, the report of the conference of the Sections delegates for 1913. This convention was held at Cooperstown. There the question of co-operation was taken up to a considerable extent, and Mr. Ralph H. Rice, who was at that time Chairman of the Chicago Section, at that meeting gave us rather a full report of the methods of bringing about co-operation between the Societies in the City of Chicago.

The following is quoted from the report of Chairman Rice at the Cooperstown Convention in 1913.

"Four years ago we started a plan of co-operation which has been very successful. The Western Society of Engineers has its headquarters in Chicago, and numbers something like 1 100 members, I believe. They have an Electrical Section, among others, and we join with that Section, so we hold monthly joint meetings of the American Institute of Electrical Engineers, Chicago Section, and the Electrical Section of the Western Society of Engineers. These meetings are very successful. We have an attendance of from 100 to 150, on an average, the attendance sometimes running as high as 400 and 500—that is when Dr. Steinmetz comes out, in October.

"The method of organization is this: We have a chairman and a secretary elected every year. We have three members of the Executive Committee, one elected each year representing the American Institute of Electrical Engineers. We have three members of the Executive Committee representing the Western Society of Engineers. These eight men constitute the Executive Committee, and they handle all the affairs in these joint meetings. This year we have had one joint meeting with the National Electric Light Association, the Commonwealth Edison Company Branch, in Chicago, we also are starting to devise means now for co-operating with the newly formed branch of the American Society of Mechanical Engineers, and have had one meeting with that organization, at which Dean Goss, the President of the Society, presided, and President Mershon of the Institute gave the address of the evening.

"Now, we find that that co-operation is a thing that pays, that is the thing that I would prefer to bring here to-night, the value of co-operation with other societies. I think the plan can be worked out with very great success in probably most of the Sections."

In 1914 the same subject was treated very fully, and the method used in Boston was given to us by Mr. George W. Palmer. He says:

"As to co-operation with other societies, of which considerable was said at the Sections delegates' luncheon, in Boston, we had a Section of the American Society of Mechanical Engineers of which I am a member, the Boston Society of Civil Engineers, the oldest engineering society in the country, and, of course, our own Section. It has been the plan for some years past to hold at least three joint meetings each year, one under the auspices of each of these Sections of the engineering societies, each section in turn being responsible for the programme and having charge of the meeting. In addition to that, this last year we have had what we call our Joint Engineering Dinner, on a somewhat elaborate scale. This dinner proved to be very successful in bringing out a large attendance."

Then, at the same time, at the same meeting, the plan which was followed in Atlanta was given to us in considerable detail. Mr. A. M. Schoen, who was Chairman of the Atlanta Section at that time, gave us this. He said:

"We brought into this organization, that is now known as the Affiliated Technical Societies of Atlanta, the local branches of the American Institute of Architects, of the American Society of Mechanical Engineers, of the American Institute of Electrical Engineers, of the American Society of Civil Engineers, of the American Chemical Society, and of the Engineering Association of the South. This gave us, as I recall, a total membership of 269. By-laws were drawn up to cover this organization, and it was stated that each Branch or Section would be responsible in every way for its own members; that in case of anything arising that should be taken up with any one of those present, it would be turned back to that particular body to be dealt with by it. These different bodies were to continue their meetings, without interference on the part of the main Society, but the affiliated body would have quarterly meetings. I should explain that there is an Executive Committee in charge of this affiliated body, and this Executive Committee is made up by an appointee from each one of the Societies, and that Executive Committee elects its own officers. The Chairman of the Executive Committee opens the meeting, and then turns it over to the particular Branch or Section that will have it in charge."

Coming down to the meeting that we had last year at Deer Park, the plan which is being followed in Philadelphia was given in some detail. Possibly you gentlemen here are familiar with that plan. There they have taken the Engineers' Club of Philadelphia as the nucleus around which the various sections of the National bodies have gathered; this is a report from Mr. Sanville, who was Chairman of the Philadelphia Section and a delegate at the Deer Park Convention last year from Philadelphia.

"The Engineers' Club provides the plant, meeting rooms, restaurant, library, and all the necessary clerical services: That is, they attend to the printing and mailing of all notices. They provide the meeting room, including a lantern, and give each affiliated society the privileges of the Engineers' Club for the afternoon, evening, and night on which it holds its meeting at the club. For this privilege each affiliated society pays a fee based on its membership within a radius of 10 miles of the center of the city. The Institute Section has its monthly meetings as usual on its regular meeting days, independent of all other meetings. The other bodies follow the same practice, and the total number of technical meetings is therefore not diminished by the affiliation.

"Each affiliated society appoints one of its members who sits on the Board of Governors of the Engineers' Club. Each affiliated society also has one member on the Papers Committee of the Engineers' Club. The Chairman of that Committee is a member of the Engineers' Club, and has no other affiliation, and the Chairman of the Publication Committee of the Engineers' Club is also a member of the Papers and Meetings Committee. The other Committee members are representatives of the affiliated societies."

As I have tried to point out, it is my belief, and I think it is borne out by the reports of our various delegates and Section Chairmen, that this matter of affiliation and co-operation with the other societies is a matter which must be worked out in each center in its own way, dependent on the conditions in each particular locality. I may be wrong, but I rather doubt that there can be any definite or cast-iron rule by which co-operation can be secured in every locality.

The object, of course, of all these meetings and affiliations among the various engineers and engineering societies is to enhance the value of the engineer in his particular locality, and to give him a wider influence in general, and particularly in civic affairs.

THE CHAIRMAN.—Now, if Professor Jacobus will tell us something of the experience of the American Society of Mechanical Engineers, we will be obliged to him.

DR. D. S. JACOBUS, PRESIDENT, AM. SOC. MECH. ENGRS.—The subject before us to-night, which has been so ably discussed by Dr. Hunt, Dr. Corthell and Mr. Lincoln, is one of the most important, if not the most important, before the Engineering Societies at the present time; it is so important that I hope to be able to appear before all the Sections of the American Society of Mechanical Engineers during my term as President in an endeavor to obtain the views of the membership at large.

There was a good representation from the Sections from all parts of the country at the recent meeting of our Society in New Orleans, and in conferring with members from many different districts it would appear that there is a closer co-operation between the members of the different Sections than there is between the governing boards of the Societies. Our governing boards should get together, and the quicker we do so the better it will be for us. It certainly would be a good move to have a joint meeting of the Committees of the Sections of the several Societies, as suggested by your President, Dr. Corthell.

I agree with Mr. Lincoln that there should not be too many restrictions in the management of the Sections, especially at this time when we have not established a definite policy. Every Section has special problems of its own to deal with and must use its own methods. Our management should be broad and such as to inspire loyalty and foster co-operation. I was much gratified in meeting the members of the different Sections to find them enthusiastically in favor of co-operation, and it is, therefore, a most opportune time for the managing boards of our Societies to get together and devise a means whereby this may be accomplished in the best way for all concerned. Our members have shown such a fine example in co-operation that it only needs a little encouragement from headquarters to spread this spirit throughout the country and thereby enhance the interests of the entire Profession. I hope, therefore, that Dr. Corthell will call us together without delay.

In addition to the geographical Sections, the American Society of Mechanical Engineers has forty student branches, numbering about 1 000 student members. Young men form the life of any society, because later they will fill our places. As we grow older, we appreciate more and more that the capital of youth is a most valuable asset; in managing the affairs of our Societies, therefore, we should keep our young men well in line, for in them lies the future strength of our organizations.

THE CHAIRMAN.—We are honored, also, here to-night by the presence of W. L. Saunders, Past-President of the American Institute of Mining Engineers, and Member of some of the other Societies. I need not tell you that he is a very broad-minded man, and we would be very glad to hear from him.

W. L. SAUNDERS, M. AM. SOC. C. E., PAST-PRESIDENT, AM. INST. MIN. ENGRS.—I had hoped that Chairman Herschel, in introducing me, might define what a mining engineer really is. In this respect we labor under a disadvantage, as compared with the Civils, Mechanicals, and Electricals. The answer to the question, "What is a mining engineer?", is a difficult one.

I was once asked the following question: "If one goes digging for clams is it mining or fishing?" Professor Kemp, of Columbia, whom we all know as a distinguished mining engineer, was present when I asked this question of a large audience of engineers. Some months afterward the Professor was examining some mining properties out

West. From one of these camps he wrote me that ever since I had asked the question he had been trying to answer it and was now prepared to do so. He said, "The real answer is: The mining engineer is the clam."

The American Institute of Mining Engineers bears a somewhat different relation to its Sections than do the other National Societies. Dr. Hunt said, a moment ago, that the desirability and importance of a Section of the American Society of Civil Engineers was increased in proportion to its distance from New York. This does not apply to the Institute of Mining Engineers because of the specialties involved. Some mining engineers work underground in mines, some in the class known as precious metals, such as gold and silver, others in mines of iron, copper, etc. Then, we have metalliferous and non-metalliferous mining. Coal mining, for instance, is one of our largest industries. We have metallurgists who are classed as mining engineers, but whose work is done in the mills.

Through Local Sections our members who are interested in special departments of the mining industry get together in groups, the proceedings and deliberations bearing particularly on that special industry. One of our largest Sections, and perhaps the largest, is the Anthracite Section, at Wilkes-Barre, Pa.

The Institute inaugurated the local section policy about five years ago. We have to-day fifteen Sections, our experience being that a Section is an element of strength, adding a limb to the main body and contributing toward the general interest and prosperity of the Institute. Through Sections the membership is largely increased.

Another advantage derived from Local Sections is that the influence of the Institute may be used through its Sections to benefit the mining industry as it affects different parts of the country. For instance, I was at Reno, Nev., in September, 1915, in connection with my office as President of the Institute. The mining men there asked me what they could do through the Institute to influence mining conditions in the State. I told them that if they had a Local Section the Institute would be in a position to consider a proposition made by it bearing on any subject relating to the Engineering Profession, and that if requested by the Section the Institute would be very likely to authorize a certain line of action. Such a precedent was recently established when the Directors of the Institute were asked to favor changes in the Constitution of the State of New York. They gave power to the New York Section, which enabled it to use the influence of the Institute, through the Section, in advocating these changes.

Recently, the President of the Mining Institute of Mexico wrote to me asking for financial help, because of the extended revolution down there, which had so affected certain members of the Institute in good standing as to prevent them from keeping up their dues. The matter was referred to the Directors of the American Institute, and authority was given to organize a Mexican Section, taking over the members of the Mexican Institute in good standing. This was done and is now in effective operation.

Following are our rules governing Local Sections:

XVIII. Local Sections.

"Sec. 1. A Local Section of the Institute may be authorized by the Board at the written request of ten Members residing within an appropriate distance of a central point.

"Sec. 2. The Board shall define the territory of a Section.

"Sec. 3. Only one Section shall be authorized in one locality or district.

"Sec. 4. A Section must consist of at least twenty-five members; if its membership falls below twenty-five in number, the Board may annul the Section.

"Sec. 5. Only Members and Associates of the Institute shall be members of its Local Sections.

"Sec. 6. All Members and Associates of the Institute residing within the territory of a Section shall be eligible for membership in such Section. But any such person failing within three months, after due invitation, to become a member of such Local Section, shall thereafter be admitted to its membership and privileges only on such conditions as said Local Section shall determine. * * *

"Sec. 7. The officers of a Section shall be elected, after the formation of the Section has been duly authorized, at a meeting of the members of the Institute within the territory of said Section, called by the sponsors of the Section, notice of said meeting and its objects being given to said Members at least thirty days in advance. Officers of Local Sections shall be elected for a term not longer than one year.

"Sec. 8. The Officers of a Local Section shall be a Chairman, Vice-Chairman, Secretary, Treasurer (or Secretary-Treasurer), and such others as the Section may desire.

"Sec. 9. It shall be the policy of the Board of Directors of the Institute to contribute from its funds for the necessary running expenses of each Local Section, when and so far as practicable, an amount not exceeding, in each year, twenty-five per cent. of the dues received from the members of said Section in said year, but in no case exceeding the sum of two hundred and fifty dollars. Requests for such appropriation shall be signed by the Chairman, Secretary and Treasurer of the Section.

"Sec. 10. If the expenses of a Section exceed the appropriation made by the Board, the difference may be made up by voluntary contributions from the members of said Section, if it shall so determine. The Institute shall not be responsible for the debts of any Section. * * *

"Sec. 11. The Board reserves the right to cancel a Section, or readjust its territory.

"Sec. 12. Papers presented at Local Sections, and discussions thereon if reported, shall be the property of the Institute. They shall be submitted to the Publication Committee and published in the *Bulletin* or *Transactions* or both, if approved. Such papers shall not be published elsewhere *in extenso* without permission of the Board. The reading of a paper before a Local Section shall not carry with it the right of publication in the *Bulletin* or *Transactions* of the Institute.

"Sec. 13. Neither the author of a paper presented to a Local Section nor the Local Section shall have the right to reprint a paper or publish it in advance of the meeting without obtaining the permission of the Publication Committee of the Institute, which may refuse, or determine the details of such permission. Nothing herein shall forbid the abstracting of a paper by the press after its presentation before a Local Section.

"Sec. 14. The Institute shall print advance copies of papers offered to Local Sections, in order to facilitate discussion thereon, provided that such papers are approved for such advance publication by the Chairman or Secretary of the Local Section and by the Publication Committee of the Institute.

"Sec. 15. Papers read before a Local Section may also be offered for reading or discussion at general meetings of the Institute, and shall be given equal standing with the other papers on the program of said meeting, when approved by the Publication Committee.

"Sec. 16. Each Local Section shall transmit promptly to the Secretary of the Institute announcements of its proposed meetings and an abstract of its proceedings, including the names of authors and titles of all papers read before it, for the purpose of preparing a report thereon to be published in the *Bulletin* of the Institute, and for the purpose of enabling the Board of Directors to comply with sections 17 and 18 of these regulations.

"Sec. 17. The By-Laws and regulations of Local Sections shall be subject to the approval of the Board of Directors.

"Sec. 18. No action shall be taken by a Section which shall contravene the Constitution and By-Laws of this Institute."

The policy of the Institute has been to invite representatives from the Local Sections, who may be visiting New York, to attend the meetings of our Executive Committee and Board of Directors. This is particularly true of the Directors' meetings. We have felt that there is a difference between a Directors' meeting, acting on questions relating to the Engineering Profession, in an industry that is not in business for profit, and that of the usual Board of Directors of a corporation. The advice given by members of the Institute coming from different sections of the country has been wholesome and beneficial. It brings them in touch with the policy and the officers of the Institute, and it brings the management in touch with the special conditions which exist in different sections of the country. We have encouraged the sections to send their officers to the Annual Meetings. Recently, a resolution was adopted by our Board by which the Institute agrees to pay the transportation expenses of all the Secretaries of the Sections to the Annual Meeting of the Institute. These Secretaries get together, exchange ideas, and make reports on their return home.

The Secretary.—Mr. Chairman, I suggest that, as we have a number of our members present, who represent some of our local associations, that they be called upon for their views as to the things that those associations want, and the difficulties that they have. I suggest that Professor Marx, being the farthest off, both in this room and geographically, be called upon first.

The Chairman.—We would be very glad to hear from Professor Marx.

C. D. Marx, Past-President, Am. Soc. C. E.—Mr. President and members of the Society, there is comparatively little, it seems to me, that can be added to what has been said already in favor of co-operation. We are all aware, I think, that a problem of that kind, of National importance, is before the membership at the present time.

I sincerely trust that the problem will be solved along the lines recommended by our President, who, unfortunately, is not able to be with us to-night. I think Point A, which he has emphasized, or Division A, should be carried out. When it comes to the local organizations I feel, as Mr. Lincoln, Mr. Jacobus, and Mr. Saunders have said, that they should be given the fullest possible latitude in solving their own problems. Our Local Associations should, to my mind, co-operate to the fullest extent with the local branches of the various National organizations, and with the local branches of the other scientific associations, which may happen to exist in that community. It is merely extending, as President Corthell suggests, the same idea, which we hope to carry out on National lines, to local affairs and conditions.

The San Francisco Association, as was stated, was one of the first to be organized. We had then a somewhat moribund society, which, at one time, was very strong, indeed, the Technical Society of the Pacific Coast.

The establishment of the Local Association of Members of the American Society of Civil Engineers has led, I think, to the disappearance of that particular Society; but it was on the down grade at the time, and I hardly think that the establishment of our Local Association can be taken to task for that. Since that time both the Mechanical Engineers and the Electrical Engineers have established their own branches; and, at present, there is on foot a very strong movement to bring about the co-operation of which the others have spoken.

There has been, furthermore, in San Francisco an Engineers' Club to which, of course, all members of the various societies are eligible; but, at the same time, provision has been made that those members of the National Societies, who do not happen to be members of the Engineers' Club, can be given the privileges of the club on the evening on which the various organizations hold their special technical meetings.

In the past we have met, as others, at hotels, have had our dinner, our good social time, and have read papers. We have discussed papers furnished by the National Society, or those prepared specially by members of the Local Association; but we are working in the direction of this co-operation which seems to have been so very successful in other organizations.

The foundation of our Local Association gave us for the first time a realizing sense of what the engineer should stand for in any community. I feel sure that the founding of our Local Associations has brought the engineer into more prominence, has gained for us more respect and more regard from the public, for one thing, than we ever had before.

I think one of the most important things in connection with the local organizations is the social factor. It is good to read papers; it is good sometimes to have papers read to you, but I think it is far better that the men who are doing the work of the world to-day should be brought together into common contact. You cannot know a man and not like him as a rule, and the fact that, in the past, we have not had the opportunity of knowing our fellow members, of knowing our fellow engineers, working along other lines, has, to my mind, been a serious detriment, and has prevented that recognition of the engineer on the part of the community, which engineers were not even willing to extend to one another.

I, therefore, most heartily believe in carrying out this spirit of co-operation, and I trust that the ballot which will be counted in June will prove that the membership of the American Society believes, not only in co-operation in local affairs, but in co-operation along National lines.

The Chairman.—I see a gentleman here from the Pelican State, where they also have a local association. We would be very glad to hear from Mr. Coleman.

J. F. Coleman, M. Am. Soc. C. E.—Mr. Chairman and gentlemen of the Society: The spirit of co-operation among engineers is surely abroad in the land. It is apparent that many members of the Profession in all branches have been giving much thought to this question, and more particularly during the current year.

As it appeals to the speaker, from the practical standpoint, co-operation among engineers might be divided into five general headings:

First.—The co-operation between the National Engineering Society and its members, more especially those whose residences or places of business are remote from Society Headquarters. It would appear that this kind of co-operation may only be brought about by the local sections or chapters which have been mentioned by every preceding speaker. It is highly necessary that the co-operation between the governing board of the National Society and its members should be as complete as it is possible to make it, as otherwise the National Society cannot hope to achieve its fullest usefulness.

Second.—The co-operation of the National Engineering Societies with each other. This is hardly less important than the first kind of co-operation mentioned.

Third.—Co-operation between the National Engineering Societies and Local Engineering Societies.

Fourth.—Co-operation of Local Engineering Societies with each other; and,

Fifth.—Co-operation of local members of National Societies with each other, or, perhaps, it would be better to say co-operation between individual engineers.

The desire for co-operation of the National Engineering Society with its own members appears to be indicated by the organization of local sections or chapters.

The desire of the National Societies for co-operation with each other is shown by recent movements toward joint conference committees and similar actions.

The spirit of co-operation between National Engineering Societies and Local Engineering Societies is only beginning to make itself evident.

The same may be said of the co-operation of Local Engineering Societies with each other; and the co-operation of individual engineers with each other has heretofore been dependent on local environment or the temperament of the individual.

The speaker fully agrees with the opinion expressed by Mr. Lincoln to the effect that each particular society, and, perhaps, each particular locality, must determine for itself the best methods to adopt in order to achieve the best results from co-operation.

Experience at New Orleans and in Louisiana leads to the conclusion that, at least in that locality, the Local Engineering Society performs an important function in general co-operation.

Results there have been highly satisfactory, as far as they have gone, though it is realized that there is room for much progress in the future. The Louisiana Engineering Society was organized 19 years ago, with 25 members. It now has 250. Its membership includes all members of the National Engineering Societies who are in Louisiana. The spirit of co-operation and feeling of close camaraderie and good fellowship which has established and maintained itself between the members of that Society is worthy of just pride, and through that spirit the members of each National Society who are members of the local society have been drawn closer to each other and to their brother engineers generally, until there is quite an effective co-operation between all of them, and especially in so far as local affairs are concerned.

Every member of the Louisiana Association of Members of the American Society of Civil Engineers is a member of the Louisiana Engineering Society, and the American Society of Mechanical Engineers is also well represented in the local society. Now, if some practical plan may be evolved whereby the Louisiana Engineering Society may enter into active co-operation with other local societies and the National Societies, it will surely receive the earnest and loyal support of that Society. Such a general co-operative movement would make the Societies more useful to their members, to the communities in which they are established, and to the Nation.

It is to be hoped that the discussion which is now being pursued by all these Societies, both National and local, will eventuate in some good plan whereby this much to be desired result may be accomplished.

THE CHAIRMAN.—Gentlemen, right in the middle of this great country is the Great Mississippi Valley. We have a representative from that valley here, Mr. Jonah, of St. Louis. We would be very glad to hear from him.

F. G. JONAH, M. AM. SOC. C. E.—Mr. Chairman and gentlemen: I just want to say a word about the Local Association of the American Society of Civil Engineers in St. Louis and the Engineers' Club of St. Louis, through which we very effectually secure a great measure of co-operation between the different branches of the National Societies in that neighborhood.

Our Local Association of Members of the American Society of Civil Engineers numbers about 120. We are working under a brief constitution which was outlined by Dr. Hunt. We have meetings occasionally; when any subject arises that we think demands our consideration, we meet to discuss it, which enables us to vote intelligently on propositions affecting the National Society.

We present no papers at our local meetings. They are presented by The Engineers' Club, which Club is composed of the members of the American Society of Civil Engineers, the American Society of Mechanical Engineers, the American Institute of Mining Engineers, and the American Institute of Electrical Engineers. The architects are not in with us. Each society presents its papers before the Club. The Club maintains a *Journal,* in which they are published, together with discussions.

The meetings alternate under the auspices of first one Society and then the others; and, in fact, the election of officers in a measure alternates. This year, for instance, the President of the Club is a Mechanical Engineer. Next year he will probably be an Electrical Engineer, the next year a Civil, and so on.

We make our appeal to the public through The Engineers' Club, and it is very much more effectual than if we tried to make it through our Local Association of a smaller membership. For instance, if a measure comes up affecting the welfare of the City, we endorse it as The Engineers' Club, and it carries a great deal of weight—we flatter ourselves that it does.

Our Club now contains 532 members, the leading members of the four National Societies in our City. I believe in strong local associations of the different National Societies. I believe in having them grouped in a club, as we have in St. Louis and elsewhere.

I am not convinced of the necessity or advisability of making district organizations of these local associations to serve as intermediaries between the Local Associations and the National Societies. It strikes me that, possibly, if that were effected, either the local club or the National Society might suffer by the attention that might be given to these district organizations.

I think that the tendency of the day is to organize too many societies, publish too many journals, have too many meetings; and it is a characteristic of the American people that "where two or three are gathered together", they want to organize some kind of society—witness the new Order of the Broken Hammer, referred to by a previous speaker.

The Chairman.—A veteran of this work is Mr. Bontecou, of Kansas City. I hope he will tell us what he knows of the work in Kansas City.

D. Bontecou, M. Am. Soc. C. E.—It occurs to me that there is after all no safety in a back seat. I am a little bit uncertain as to why I should be asked to speak on the subject of local associations, unless it be, as I learned yesterday, that I was connected with the first one formed, the association at Kansas City; but there should not be very much rejoicing over the birth of that association, because I feel that it was still-born. It elected, with great enthusiasm and great unanimity, perhaps one hundred engineers as members, framed a constitution, and then did not come to any meetings; and so the association of Kansas City had to be thrown into the scrap-heap.

There may be some consolation in that, because I believe we all appreciate that even a scrap-heap is instructive, and perhaps the lesson we are to draw from that is a pretty broad one, that it meant that there was lack of appreciation, lack of interest, and lack of cohesion among the members, and probably lack of pretty much everything else that would cause a healthy and long life.

I think the situation at Kansas City is interesting in a way. In the thirty years that I have known the town the engineers have always shown a desire for some sort of association, and they have undertaken pretty nearly all the unfortunate things that could be undertaken by a body of engineers to that end and tried them out, and each has failed.

There was, in the first place, an engineers' club that could not pay its rent, and there was an engineers' club that followed that insisted upon dealing with purely national questions. It spent its time considering recommendations to Congress, and things of that kind. And then there was a technological association which depended entirely upon getting some eloquent outsider to address it at its meetings; but the supply of eloquent men soon ran out, and there was nothing left. And then there was this association that I spoke of; and now there is an engineers' club which has been groping along in more or less trouble; and I gather from what I know of it that it is not exactly in a flourishing condition. It has reached a point where the members of the American Society of Civil Engineers are quite seriously considering the propriety of forming an Engineers' Branch of this Society, where engineers may go and say or hear something that relates in some way or other to engineering.

The effect of it to me is quite evident; and I do not know how the situation ought to be met. I hoped to hear something that would help me to a conclusion to-night. For instance, not very long ago, an engineer said to me, why is it that one engineer always knocks another engineer, and he honestly felt that what he said was true. I do not know whether it is or not; I do not believe it is; but probably there are too many occurrences that suggest it.

Of course, the difficulties are great in a place where there are not a large number of engineers, where only 25 or 30 men can be depended upon for the total membership, and where many questions are to be considered, as, for instance, that of expense, of a place to meet, and the dread some people have of going to a meeting where they may have to sit through a paper that is dreary. They have trouble enough the rest of the time without listening to that.

I have reached one conclusion as to the preliminaries necessary for the formation of an association, namely, on these questions of local interest that have been referred to, and think that the business of a local association is to interest itself with local questions, where its members are surer to find a common meeting ground than in any other way. Engineers can render service to the community they live in, and by doing so help their association and themselves.

The Chairman.—I am sorry we have nobody here from Boston to speak to us on this subject. I happen to know that it is a very live community in the matter of local associations of engineers, all of them working together.

A MEMBER.—I see Professor Swain at the back of the room.

THE CHAIRMAN.—Do you? I was looking for him. Professor Swain, please come forward. That is one of the advantages of the back seat that was alluded to a moment ago. I had not seen him. We will be very glad to hear from Professor Swain.

GEORGE F. SWAIN, PAST-PRESIDENT, AM. SOC. C. E.—Mr. Chairman and gentlemen, I was in hopes that you had not seen me, and that nobody else had seen me, because I have really nothing to add to what has been said this evening, to all of which I have listened with a great deal of interest, and with which I cordially agree. We are all members of one profession, not of several; and we can make our influence most felt, of course, by the highest degree of co-operation. It is not very profitable to reflect on what we would have done under other conditions, but I have sometimes considered what would have been the best organization of our engineering societies, if they had been established at one time, at this present time, for instance. We have grown up in a hap-hazard sort of way by differentiation of the various branches of engineering; but I have come to the conclusion that if I were asked to-day to organize the Engineering Profession, I would have but one society, one society of American Engineers, including all branches of the Profession, with sections and local associations, so that the different members could discuss the technical subjects in which they were specially interested, just as they do to-day, but not as separate societies.

It has occurred to me, in listening to what has been said to-night, that there is a deeper side to all this subject of co-operation, which we all desire to bring about. The object of this is to increase the prestige and the influence of the Profession, to get for ourselves all that we can in the way of position and influence and power and wealth, if you like, and also to make our Profession of the greatest real use to the community. These are all legitimate objects, for any man or any society or any profession. Why do we want to get them, and what must we do in order to get them?

In the first place, in order to get these things we must make ourselves deserving of them. We must make the Engineering Profession worthy of the great place, the great influenee, which it ought to hold in the community. We must realize that there is something besides the material side and aspect of all this question. We have duties as citizens, as individuals, in this great country, entirely aside from our duties and interests as engineers; and in meeting these we can do a great deal by co-operation. In all these respects the motto "United we stand, divided we fall," holds, not only for individuals, but for societies and for members of the different branches of the Profession.

We are products, each one of us, of our environment and our heredity, and of what has gone before. How can we influence those who are to come after us for their good? One of the great influences is education; and I fail to see that the Engineering Profession, as a profession, has done very much to influence education in this country. We take the education that is given to us, that others decide we ought to have. I think there is a great opportunity, for the Engineering Profession, in trying to influence the character of the future members of our own Profession; and I wish that we, in co-operating, could get a little apart from the mere technical details that we are so apt to discuss at our meetings, and think of the deeper things, of which education is only one.

Now, we as engineers tend to become materialistic. We are applied scientists. We deal with the applications of the laws of Nature, and with the materials of Nature, and the study of these naturally tends to make a man materialistic, and to divert his thoughts from the deeper things. We must work against this tendency. We must not allow ourselves as workers in material things, to be removed from the real deep things of life.

We realize this to a certain extent. We have codes of ethics, and so forth, and we realize that we have certain ethical relations and duties; but codes of ethics will do no good if we excuse or connive at, or fail to treat with seriousness, flagrant violations of those codes. We must realize in all of this discussion of co-operation and of what we are trying to do to increase our influence, our prestige, our power, our representation, that there is a moral and an ethical side to the whole question, which is much more important than the material side.

THE CHAIRMAN.—Having now exhausted the draft, I will call for volunteers, and will be very glad to hear from anybody on this general subject of sections or local associations.

THE SECRETARY.—Mr. Chairman, I would like to suggest that you have not exhausted the draft, for Mr. Crocker, of Denver, the first President of the Colorado Association, is here.

THE CHAIRMAN.—I had forgotten Denver. Mr. Crocker, we would be very glad to hear from you.

H. S. CROCKER, M. AM. SOC. C. E.—Mr. President and gentlemen, before I came here to-night, Mr. Hunt made me a promise that I would not be asked to say anything, so I am not prepared to say very much. The Colorado Association, as has been said, was organized in 1908, and we had at the start 53 members. We now have a total of about 75 members out of a membership in the State of Colorado of about 104.

The Association has been very successful, especially in making the members acquainted with each other, and with the work that is done by each. I think that we are working together much better than we ever did before. Lately, we have been confronted with a question, to which we will have to give considerable thought, that is, the arrangement which we may be able to make for co-operation with the local branches of other societies. Prior to the organization of our Association there existed in Colorado the Colorado Scientific Association, which, at the present time, has about 225 members. This has decreased somewhat since the organization of the branches of the National Societies, and the Scientific Association has taken the initiative in suggesting some form of co-operation, by which we will have joint meetings and possibly joint headquarters, with some kind of common organization.

The greatest problem with us is the question of expense. When we organized our Association we decided on yearly dues of $2, which are rather small for any organization, barely covering postage and notices; and, as is known, it has not been the policy of our Parent Society to rebate to any of our local members a portion of their dues on account of their belonging to local associations. I do not know that that is desirable, but, as it is now, of this Colorado Scientific Association there are 60 members belonging to these various societies, and we must devise some means of arranging for joint meetings.

The first meeting we had was last Saturday night. It was conducted by the local members of the Institute of Electrical Engineers. It was one of the most successful meetings we have had. The subject under discussion was "Railroad Electrification". The attendance was about 75, which was unusually large for one of our meetings, and the enthusiasm was accordingly great. A programme was given, so that I think that all our members will feel that we will do much more in the line of joint meetings. I consider it a great privilege to have been present to-night and to have heard the gentlemen who represent the other Societies, because, in Colorado, we certainly want to go in with the local members of those Societies, and do all we can to get acquainted and work together.

The Secretary.—Mr. Chairman, I just happened to see in the room Mr. John Bogart, who was Secretary of this Society before any of the other National Societies, with the exception, I think, of the Mining Engineers, were formed. He may have some ideas to express on this subject.

The Chairman.—Mr. John Bogart.

John Bogart, M. Am. Soc. C. E.—Mr. Chairman and gentlemen, it seems to me that this subject has been so thoroughly discussed this evening that there is very little to be added. I was the Secretary of this Society before any of the other National organizations were formed, except the Mining Engineers. In fact, I helped in the organization of the Mechanical Engineers, and it was effected largely in the office of the Secretary of the American Society of Civil Engineers. The organization of the American Institute of Electrical Engineers was also effected in my office, when I was Secretary of the American Society of Civil Engineers; and I was very glad to be able, in each of those cases, to help with such advice as was possible, the men who felt that it was important to organize those special societies.

All through my connection with the Board of Direction of the American Society of Civil Engineers—which was a good many years, not only as Secretary, but also as a Director—this matter of what could be done to have some local meetings of interest, and to take care of members of the Society at all points in the United States, was discussed and was thought of very much indeed. It seems to me that the organization of these local sections, as has been outlined here and has been going on, is a wonderful step in advance toward the realization of the best interests of the Profession.

I was deeply interested in what Professor Swain said, with which I most heartily agree. I wish it had been possible that there should have been, instead of these different National Societies, one great National Society, in which each of the different branches of the Profession would have its equal part; and possibly the association of local organizations may lead to a much better realization of that ideal than has been attained up to this time.

* * * * * * *

OTIS F. CLAPP, M. AM. SOC. C. E.—Mr. Chairman, I move that the discussion that is now before us be published by the Society, after proper revision.

THE CHAIRMAN.—Mr. Clapp moves that the discussion here to-night be published in the *Proceedings* of the Society.

(Motion seconded.)

THE CHAIRMAN.—All in favor of the motion say "Aye"; contrary minded, "No". It is a vote.

THE CHAIRMAN.—If there is no further business, a motion to adjourn will be in order, but first let me express our thanks to the gentlemen who have addressed us this evening.

Adjourned.

SOCIETY ITEMS OF INTEREST

Admission Requirements

Rules Adopted by the Board of Direction in Regard to Requirements for Admission to the Various Grades of Membership in the Society, April 18th, 1916*

The requirements fixed by the Constitution are intended to mark the minimum which should be recognized for admission to membership, and the maintenance of a high standard necessitates that these provisions should be interpreted conservatively to the end that the fitness of applicants shall be established beyond a doubt.

In order to shape more definitely the requirements in the classification of applicants for admission or for transfer, and to assure as far as possible that applicants for membership meet the spirit of the requirements established by the Constitution, it is the sense of this Board that:

(1) No applicant shall be admitted to any grade whose qualifications are not shown to be clearly equal to the requirements of the Constitution.

(2) In order to insure the fulfillment of these requirements, each applicant for admission or for transfer shall be required to furnish, if possible, the names of persons, whether members of the Society or not, who have personal knowledge of his work in each of the positions enumerated in his application. If possible, he shall name more than five references, and his application shall state in detail the character and extent of the works upon which he has been engaged, and the degree to which he was responsible for their design and execution.

(3) In considering the requirements for the grade of Member the words "responsible charge of work" shall be interpreted to refer to work of considerable magnitude for which rule-of-thumb methods are not sufficient.

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* In spite of the most careful scrutiny of all applications, criticism of the action of the Board in specific cases (that it has either been too lenient or too severe), has been heard. The above rules were the result of very full consideration of the subject, the object being to render as uniform as possible the treatment of all applications.

These rules should be substituted for those previously issued and printed on page 35 of the Year Book for 1916.

ANNOUNCEMENTS

The House of the Society is open from 9 A. M. to 10 P. M., every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

FUTURE MEETINGS

June 7th, 1916.—8.30 P. M.—This will be a regular business meeting. Two papers will be presented for discussion, as follows: "The Preservation of Sandy Beaches in the Vicinity of New York City", by Elliott J. Dent, M. Am. Soc. C. E.; and "The Properties of Balsa Wood (*Ochroma Lagopus*)", by R. C. Carpenter, M. Am. Soc. C. E.

These papers are printed in this number of *Proceedings.*

September 6th, 1916.—8.30 P. M.—A regular business meeting will be held, and a paper by J. C. Allison, Assoc. M. Am. Soc. C. E., entitled "Control of the Colorado River as Related to the Protection of Imperial Valley", will be presented for discussion.

This paper is printed in this number of *Proceedings.*

ANNUAL CONVENTION

The Forty-eighth Annual Convention of the Society will be held at Pittsburgh, Pa., from June 27th to 30th, 1916, inclusive.

Arrangements for the Convention are in the hands of the following Local Committee:

George S. Davison, *Chairman,*

J. A. Atwood,	D. W. McNaugher,
R. A. Cummings,	Emil Swensson,
Richard Khuen,	E. B. Taylor,
Morris Knowles,	W. G. Wilkins,

Paul L. Wolfel.

A circular containing information as to the general programme, transportation, hotel rates, etc., has been issued to the membership.

SEARCHES IN THE LIBRARY

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

It sometimes happens that references are found which are not readily accessible to the person for whom the search is made. In that case the material may be reproduced by photography, and this can be done for members at the cost of the work to the Society, which is small. This method is particularly useful when there are drawings or figures in the text, which would be very expensive to reproduce by hand.

PAPERS AND DISCUSSIONS

Members and others who take part in the oral discussions of the papers presented are urged to revise their remarks promptly. Written communications from those who cannot attend the meetings should be sent in at the earliest possible date after the issue of a paper in *Proceedings.*

All papers accepted by the Publication Committee are classified by the Committee with respect to their availability for discussion at meetings.

Papers which, from their general nature, appear to be of a character suitable for oral discussion, will be published as heretofore in *Proceedings,* and set down for presentation to a future meeting of the Society, and on these, oral discussions, as well as written communications, will be solicited.

All papers which do not come under this heading, that is to say, those which, from their mathematical or technical nature, in the opinion of the Committee, are not adapted to oral discussion, will not be scheduled for presentation to any meeting. Such papers will be published in *Proceedings* in the same manner as those which are to be presented at meetings, but written discussions only will be requested for subsequent publication in *Proceedings* and with the paper in the volumes of *Transactions.*

The Board of Direction has adopted rules for the preparation and presentation of papers, which will be found on page 429 of the August, 1913, *Proceedings.*

LOCAL ASSOCIATIONS OF MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

San Francisco Association

The San Francisco Association of Members of the American Society of Civil Engineers holds regular bi-monthly meetings, with banquet, and weekly informal luncheons. The former are held at

6 P. M., at the Palace Hotel, on the third Tuesday of February, April, June, August, and October, and the third Friday of December, the last being the Annual Meeting of the Association.

Informal luncheons are held at 12.15 P. M., every Wednesday, and the place of meeting may be ascertained by communicating with the Secretary of the Association, E. T. Thurston, 713 Mechanics' Institute, 57 Post Street.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in San Francisco, and any such member will be gladly welcomed as a guest.

Colorado Association

The meetings of the Colorado Association of Members of the American Society of Civil Engineers (Denver, Colo.) are held on the second Saturday of each month, except July and August. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary, L. R. Hinman, 1400 West Colfax Ave., Denver, Colo. The meetings are usually preceded by an informal dinner. Members of the American Society of Civil Engineers will be welcomed at these meetings.

Weekly luncheons are held on Wednesdays, at 12.30 P. M., at Clarke's Restaurant, 1632 Champa Street.

Visiting members are urged to attend the meetings and luncheons.

(Abstract of Minutes of Meetings)

March 11th, 1916.—The meeting was called to order at the Denver Athletic Club; President John E. Field in the chair; L. R. Hinman, Secretary; and present, also, 19 members.

The minutes of the meeting of February 12th, 1916, were read and approved.

On motion, duly seconded, the resignations of Messrs. Orrin Randolph and William A. Smith, as members of the Association, were accepted.

On motion, duly seconded, the resolutions on the death of George Lenox Crawford, Assoc. M. Am. Soc. C. E., were adopted and ordered spread upon the records of the Association. A copy of the resolutions was also ordered to be sent to his family.

The discussion of the six questions submitted to the membership of the Society by the Committee on Revision of the Constitution, was opened by Messrs. Ridgway, Toll, Comstock, Vincent, Ketchum, and Follansbee, to whom they had been assigned, and the subjects were generally discussed by those present.

A letter from John A. Ockerson, Past-President, Am. Soc. C. E., relative to the change of Society headquarters, was read, but owing to lack of time discussion was deferred until some future meeting.

Adjourned.

April 15th, 1916.—The meeting was called to order at the Denver Athletic Club, and was held in joint session with the Local Chapter of the American Institute of Electrical Engineers; President Carter of that Chapter in the chair; L. R. Hinman, Secretary; and present, also, 70 members and guests.

President Field of the Association, introduced Charles D. Marx, Past-President, Am. Soc. C. E., and Edwin Duryea, Jr., Director, Am. Soc. C. E., the guests of the Association.

Mr. H. S. Crocker, who was recently appointed to represent the Society on the Colorado Committee on Industrial Preparedness, addressed the meeting briefly on the duties of that Committee.

Mr. W. H. Edmunds, of the Denver and Interurban Railroad, presented a paper on "Steam Railroad Electrification", illustrating his remarks with lantern slides, and the subject was generally discussed by those present.

Adjourned.

Atlanta Association

The Atlanta Association of Members of the American Society of Civil Engineers was organized on March 14th, 1912. The Association holds its meetings at the University Club, Atlanta, Ga.

Regular monthly luncheon meetings are held to which visiting members of the Society are always welcome.

(Abstract of Minutes of Meeting)

April 11th, 1916.—The meeting was called to order, the guest of the evening being George C. Scales, Assoc. M. Am. Soc. C. E., Highway Engineer, U. S. Office of Public Roads and Rural Engineering.

The minutes of the previous meeting were read and approved.

The following officers were elected for the ensuing year: President, Paul H. Norcross; First Vice-President, V. H. Kriegshaber; Second Vice-President, William C. Spiker; and Secretary-Treasurer, Thomas P. Branch.

It was the consensus of opinion that the Local Association, as a body, approved of the removal of the headquarters of the Society to the United Engineering Building, the details being subject to the approval of the Board of Direction.

Local problems pertaining to the State Highway Commission, City Plan schemes, and Sanitary Laws, were subjects of general discussion by those present.

Adjourned.

Baltimore Association

The Baltimore Association of Members of the American Society of Civil Engineers was organized on May 6th, 1914, and the proposed Constitution was approved by the Board of Direction at its meeting of September 2d, 1914.

At the meeting of the Association on May 5th, 1915, the following officers were elected: President, Thomas D. Pitts; Secretary-Treasurer, Charles J. Tilden; Directors, J. E. Greiner, C. W. Hendrick, B. P. Harrison, B. T. Fendall, Mason D. Pratt, R. Keith Compton, R. B. Morse, and H. G. Shirley.

Cleveland Association

The proposed Constitution of the Cleveland Association of Members of the American Society of Civil Engineers was considered and approved by the Board of Direction of the Society on January 6th, 1915.

At the meeting of the Association on December 18th, 1915, the following officers were elected for the ensuing year: President, Robert Hoffmann; Vice-President, Wilbur J. Watson; and Secretary-Treasurer, George H. Tinker.

Louisiana Association

At the meeting of the Louisiana Association of Members of the American Society of Civil Engineers (New Orleans, La.), on April 14th, 1915, the following officers were elected for the ensuing year: J. F. Coleman, President; W. B. Gregory and A. M. Shaw, Vice-Presidents; Ole K. Olsen, Treasurer; and E. H. Coleman, Secretary.

Northwestern Association

The proposed Constitution of the Northwestern Association of Members of the American Society of Civil Engineers (St. Paul and Minneapolis, Minn.) was considered and approved by the Board of Direction of the Society on November 4th, 1914.

The officers of the Association are as follows: President, W. L. Darling; First Vice-President, George L. Wilson; Second Vice-President, L. W. Rundlett; Secretary, R. D. Thomas; and Treasurer, A. F. Meyer.

Philadelphia Association

The meetings of the Philadelphia Association of Members of the American Society of Civil Engineers are held at the Engineers' Club of Philadelphia, 1317 Spruce Street.

The officers of the Association are as follows: President, Edward B. Temple; Vice-Presidents, Edgar Marburg and John Sterling Deans; Directors, J. W. Ledoux, H. S. Smith, Henry H. Quimby, and George A. Zinn; Past-Presidents, George S. Webster and Richard L. Humphrey; Treasurer, S. M. Swaab; and Secretary, W. L. Stevenson.

(Abstract of Minutes of Meeting)

April 3d, 1916.—The meeting was called to order at the Engineers' Club of Philadelphia; President Edward B. Temple in the chair; W. L. Stevenson, Secretary; and present, also, 40 members and guests.

The appointment of Mr. C. W. Thorn, as Assistant Secretary, was announced.

Dr. Edgar Marburg reported briefly *in re* the licensing of structural engineers.

The origin and purpose of the proposed "District Organizations" were described by Mr. Richard L. Humphrey, and the following resolution was adopted unanimously:

"*Resolved:* That this Association reiterates its endorsement of February 24th, 1915, of 'District Organizations' as proposed by the Conference of Presidents of the Local Associations held on January 19th, 1915, and instructs the Secretary to request our membership to vote for the revision of the Constitution of the Society to provide for 'District Organizations' and to notify the other Local Associations of this action and to request the favorable consideration of this matter by each of the other Associations and their members."

President Temple was elected as the representative of the Association on the Board of Directors of the Engineers' Club.

Clemens Herschel, Vice-President, Am. Soc. C. E., addressed the meeting on the proposed change of Society headquarters. Letters and telegrams from members of the Society in favor of and opposed to the proposition were read, and the subject was discussed by Messrs. E. J. Mehren, Charles Whiting Baker, and many members of the Association present.

After discussion, the following form of resolutions, which had been endorsed by the Board of Directors, was adopted unanimously:

"*Whereas,* An unofficial circular letter, dated February 12, 1916, addressed to 'the Members of the American Society of Civil Engineers,' has been sent to the Philadelphia Association of Members of the American Society of Civil Engineers, and to each of the fourteen other Local Associations of the American Society of Civil Engineers, by its author, Mr. J. A. Ockerson, Past-President of the Society; and

"*Whereas,* This letter contains the following statements:

"'An invitation has been extended to the American Society of Civil Engineers to enter 'the United Engineering Society as an additional Founder Society.' This invitation itself shows that the destinies of the 'Founder Societies' is largely if not wholly controlled by a superior authority, and the fact must not be overlooked that the relationship which exists between the United Engineering Society and the Founder Society which gives the former authority over them, has not been presented in detail to our members.

"'Suppose we become an 'additional Founder Society' and desire to put before the public a measure which we have conceived and which we deem important. It must have the sanction of the United Engineering Society, representing a majority of the Founder Societies, which can prevent action, or, if approved, the United Engineering Society would stand before the public as the sponsor of the measure. This illustration applies equally to all of the Founder Societies;' and

"*Whereas,* It appears from the results of inquiries in authoritative quarters that these statements have no basis in fact, and that they are, therefore, calculated to influence unfairly votes on the pending measure by which the American Society of Civil Engineers has been given an opportunity to become one of the Founder Engineering Societies in relation to the United Engineering Society; be it hereby

"*Resolved,* As the sense of this meeting, that this situation be brought promptly to the notice of the Board of Direction of the American Society of Civil Engineers through these resolutions, and that it be recommended to the Board, in the interest of fair play in a matter of momentous importance to the Society, that the Board issue an announcement to the membership-at-large, and at the earliest possible date, in official certification to the correctness or incorrectness of Mr. Ockerson's previously-quoted statement."

A vote of thanks to Messrs. Herschel, Mehren and Baker was passed.

Adjourned.

Portland, Ore., Association

At the Annual Meeting of the Association on September 28th, 1915, the following officers were elected for the ensuing year: President, J. P. Newell; First Vice-President, John T. Whistler; Second Vice-President, E. B. Thomson; Treasurer, Russell Chase; and Secretary, J. A. Currey.

St. Louis Association

The proposed Constitution of the St. Louis Association of Members of the American Society of Civil Engineers was considered and approved by the Board of Direction of the Society on October 7th, 1914.

The following officers have been elected: President, J. A. Ockerson; First Vice-President, Edward E. Wall; Second Vice-President, F. J. Jonah; Secretary-Treasurer, Gurdon G. Black. The meetings of the Association are held at the Engineers' Club Auditorium.

San Diego Association

The San Diego Association of Members of the American Society of Civil Engineers was organized on February 5th, 1915, and officers have been elected, as follows: President, George Butler; Vice-President, Willis J. Dean; and Secretary-Treasurer, J. R. Comly.

At its meeting of September 20th, 1915, the Board of Direction considered and approved the proposed Constitution of the San Diego Association of Members of the American Society of Civil Engineers.

Seattle Association

The Seattle Association of Members of the American Society of Civil Engineers was organized on June 30th, 1913.

The officers of the Association for 1916 are as follows: President, A. O. Powell; Vice-President, Joseph Jacobs; and Secretary-Treasurer, Carl H. Reeves.

(Abstract of Minutes of Meeting)

April 24th, 1916.—The meeting was called to order at 12.15 P. M., at the Northold Inn; President A. O. Powell in the chair; Carl H. Reeves, Secretary; and present, also, 15 members and guests.

The minutes of the meeting of March 27th, 1916, were read and approved.

The resignation of Mr. E. C. Macy, as a member of the Association, owing to removal from the district, was read and accepted.

Mr. G. R. Edwards was appointed a member of the Legislative Committee to succeed Mr. J. B. Warrack, resigned.

President Powell addressed the meeting on the subject of Industrial Preparedness as outlined by the Naval Consulting Board and the Secretary of the Navy, describing the plan of work by districts under the direction of the representatives chosen from the National Engineering Societies, and urging the importance of volunteer aid by members of the Association in making this industrial census.

Adjourned.

Southern California Association

The Southern California Association of Members of the American Society of Civil Engineers (Los Angeles, Cal.) holds regular bi-monthly meetings, with banquet, on the second Wednesday of February, April, June, August, October, and December, the last being the Annual Meeting of the Association.

Informal luncheons are held at 12.15 P. M. every Wednesday, and the place of meeting may be ascertained from the Secretary of the Association, W. K. Barnard, 701 Central Building, Los Angeles, Cal.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in Los Angeles, and any such member will be gladly welcomed as a guest at any of the meetings or luncheons.

The officers of the Association for 1916, are as follows: President, William Mulholland; First Vice-President, H. Hawgood; Second Vice-President, L. C. Hill; Secretary, W. K. Barnard; and Treasurer, C. H. Lee.

Spokane Association

The proposed Constitution of the Spokane Association of Members of the American Society of Civil Engineers was considered and approved by the Board of Direction of the Society on March 4th, 1914. Ulysses B. Hough is President.

Texas Association

The proposed Constitution of the Texas Association of Members of the American Society of Civil Engineers was considered and approved by the Board of Direction of the Society on December 31st, 1913. The headquarters of the Association is Dallas, Tex. John B. Hawley is President.

MINUTES OF MEETINGS OF SPECIAL COMMITTEES TO REPORT UPON ENGINEERING SUBJECTS

Special Committee on Stresses in Railroad Track.

January 18th, 1916.—The meeting was held at the Society House. Present, A. N. Talbot (Chairman), A. S. Baldwin, C. G. E. Larsson, and William McNab (of the Committee), and also W. M. Dawley and P. H. Dudley (of the American Railway Engineering Association).

There was an informal presentation and discussion of the results of the experimental work carried out in 1915. A report of progress was put in final form for presentation to the American Society of Civil Engineers and the American Railway Engineering Association.

March 21st, 1916.—The meeting was held at the Congress Hotel, Chicago, Ill. Present, A. N. Talbot (Chairman), A. S. Baldwin, J. B. Berry, G. H. Bremner, John Brunner, W. J. Burton, Charles S. Churchill, W. C. Cushing, —— Gennett (representing Robert W. Hunt), Paul M. La Bach, C. G. E. Larsson, William McNab, G. J. Ray, and F. E. Turneaure (of the Committee), and also W. M. Dawley, P. H. Dudley, J. B. Jenkins, and Earl Stimson (of the American Railway Engineering Association).

The report of experimental work carried on in 1915 was presented and discussed in detail. There was a discussion of the nature of the work to be carried on during the coming season. The proposed instrument of Mr. John Brunner for determining the lateral pressure against the rail was described. It was decided to hold a meeting in Champaign-Urbana to consider the results of the experimental work and the programme for the coming season.

Special Committee on Materials for Road Construction

February 5th, 1916.—The meeting was held at the House of the Society. Present, W. W. Crosby (Chairman), A. W. Dean, Nelson P. Lewis, Charles J. Tilden, and A. H. Blanchard (Secretary).

The minutes of the meeting of November 4th, 1915, were read and approved.

A communication from Charles Warren Hunt, Secretary of the Society, pertaining to appropriations for the work of the Committee, was read.

The Chairman outlined the work of the Committee for 1916, and reviewed the opinions expressed at the Annual Meeting, relative to broadening the scope of the work of the Committee.

A resolution was adopted to the effect that although the Committee does not believe it to be expedient, practicable or consistent with the general policy of the Society to frame detailed specifications for the different types of roads and pavements, it proposes to include in its next report the fundamental considerations which should govern the framing of such specifications and which might even be included in them, and a copy of the resolution was ordered to be forwarded to the Board of Direction.

On motion, duly seconded, the Chairman was authorized to make assignments of the several sections of the 1917 Report to the various members of the Committee.

It was decided that the next meeting of the Committee should be held during the latter part of April, 1916.

April 22d, 1916.—The meeting was called to order at 10 A. M., at the House of the Society. Present, W. W. Crosby (Chairman), H. K. Bishop, Nelson P. Lewis, Charles J. Tilden, George W. Tillson, and A. H. Blanchard (Secretary).

The minutes of the meeting of February 5th, 1916, were read and approved.

The outline and scope of the 1917 Report were discussed at length, and reports by Sub-Committees on Gravel Roadways, and Cement-Concrete, Brick, Stone Block, Wood Block, Bituminous Concrete, Asphalt Block, and Sheet-Asphalt Pavements, were considered.

It was decided that the next meeting of the Committee should be held about the middle of June, 1916, the date to be decided by the Chairman.

Special Committee on Concrete and Reinforced Concrete

March 28th, 1916.—The meeting was called to order at 10.10 A. M., at the House of the Society. Present, J. R. Worcester (Chairman), Robert W. Lesley, A. N. Talbot, and Richard L. Humphrey (Secretary).

The Report of the Sub-Committee on Ways and Means was considered, and the report of the Chairman relative to correspondence with the Secretary of the Society concerning finances was received.

The Secretary was instructed to prepare 100 page-proof copies of the report of the Committee, embodying all changes to date, to be sent to the members of the Committee in advance of its consideration at the next meeting.

The proposed recommendations for flat slab design were discussed.

The proposed survey of existing buildings was discussed by Professor Talbot, who stated that although he felt that it would give results of value, it would take time, and that probably this information would not be available for the June meeting.

It was agreed to make a survey of existing buildings for the purpose of analysis, and that such survey should include: 1, The Design; 2, The Loading; and 3, The Present Condition.

The Sub-Committee on Design was requested to formulate instructions for the work, and it was suggested that each member be asked to report on such flat slab structures as were accessible to him.

Special Committee on Steel Columns and Struts

April 6th, 1916.— The meeting was called to order at 10 A. M., at the Bureau of Standards, Washington, D. C. Present, George H. Pegram (Chairman), James H. Edwards, Clarence W. Hudson, Rudolph P. Miller, and Lewis D. Rights (Secretary). There were also present W. H. Moore, M. Am. Soc. C. E., representing the Steel Column Sub-Committee of the American Railway Engineering Association, and Dr. G. R. Olshausen, representing the Bureau of Standards. R. B. Woodworth, M. Am. Soc. C. E., of the Carnegie Steel Company, and A. B. Ilsley, Assoc. M. Am. Soc. C. E., of the Southern Railway Company, were present as invited guests.

The minutes of the meeting of January 20th, 1916, which had been previously distributed by mail to all members of the Committee, were approved as written.

Dr. Olshausen reported that he had considered the question of initial sets in connection with tests of six columns, slenderness ratio, $20\frac{l}{r}$, Type 1, three light and three heavy sections, and that he had plotted stress strain curves for these six tests, but had not given the matter as much study as he desired. On motion, the matter of initial sets and repeated loads was referred to Dr. Olshausen, as a Committee of one, to report on at the next meeting.

Professor Swain (who was not present) was continued as a Committee of one on Watertown Tests, to confer with Col. Wheeler, of Watertown Arsenal, and report at a later meeting.

Mr. Edwards reported for the Committee on Transverse Tests, consisting of himself and Messrs. Swain and Olshausen, outlining a proposed method of making three tests with transverse loadings. The Committee was continued.

Mr. Miller reported progress on 8-in. strain gauge measurements, and was continued as a Committee of one.

The discussion of Mr. Worcester's report on Safe Working Values called attention to the fact that to date only Messrs. Edwards, Modjeski, and Rights had submitted discussions on the subject. On motion, the Secretary was instructed to request all the other members of the Committee to submit discussions at once, so that the views of all the members would be before the Committee at the next meeting.

The Committee then adjourned to witness a test on a heavy Bethlehem section column, slenderness ratio, 50 $\frac{l}{r}$, and after its failure, the members were the guests of Dr. S. W. Stratton, Director of the Bureau of Standards, at luncheon.

After luncheon, the Committee discussed the wisdom at this time of arranging with the Bureau of Standards to have the Government purchase columns for additional supplementary programmes, and the subjects of special steels, transverse tests, and long columns with slenderness ratios up to 200 $\frac{l}{r}$. It was decided that the work of investigating and interpreting the programme, as now outlined, was sufficient to take up the time of the Committee for the present.

Relative to the plotting of the results of tests made thus far, Dr. Olshausen reported that he was making specimen tensile and compression tests covering material taken from the same heats as the columns. It was thought that these specimen tests would assist the Committee in explaining the reason for the low failure values of the heavy columns, and Dr. Olshausen was requested to arrange to plot the stress strain curves for the specimen tests alongside of those for the columns.

After examining the curves now plotted by the Bureau of Standards, the Committee adjourned at 2.30 P. M., to meet at the call of the Chair.

Special Committee on Valuation of Public Utilities

April 11th, 12th, 13th, and 14th, 1916.—Nine sessions were held at the Society House. Present, F. P. Stearns (Chairman), C. S. Churchill, W. G. Raymond, H. E. Riggs, W. J. Wilgus, and J. P. Snow (Secretary *pro tem.*).

Arrangements were made for perfecting and printing, in galley form, the table of contents; introduction; glossary; fundamental principles of valuation; property to be included in physical valuation; and original cost to date.

The chapters on Reproduction Cost, Depreciation and Appreciation, Development Expense, and Non-Physical Values, were discussed, and arrangements were made for revision and discussion before printing.

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms, and at all meetings:

American Institute of Electrical Engineers, 33 West Thirty-ninth Street, New York City.

American Institute of Mining Engineers, 29 West Thirty-ninth Street, New York City.

American Society of Mechanical Engineers, 29 West Thirty-ninth Street, New York City.

Architekten=Verein zu Berlin, Wilhelmstrasse 92, Berlin W. 66, Germany.

Associação dos Engenheiros Civis Portuguezes, Lisbon, Portugal.

Australasian Institute of Mining Engineers, Melbourne, Victoria, Australia.

Boston Society of Civil Engineers, 715 Tremont Temple, Boston, Mass.

Brooklyn Engineers' Club, 117 Remsen Street, Brooklyn, N. Y.

Canadian Society of Civil Engineers, 176 Mansfield Street, Montreal, Que., Canada.

Civil Engineers' Society of St. Paul, St. Paul, Minn.

Cleveland Engineering Society, Chamber of Commerce Building, Cleveland, Ohio.

Cleveland Institute of Engineers, Middlesbrough, England.

Dansk Ingeniorforening, Amaliegade 38, Copenhagen, Denmark.

Detroit Engineering Society, 46 Grand River Avenue, West, Detroit, Mich.

Engineers and Architects Club of Louisville, 1412 Starks Building, Louisville, Ky.

Engineers' Club of Baltimore, 6 West Eager Street, Baltimore, Md.

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Institution of Engineers of the River Plate, Calle 25 de Mayo 195, Buenos Aires, Argentine Republic.

Institution of Naval Architects, 5 Adelphi Terrace, London, W. C., England.

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Louisiana Engineering Society, State Museum Building, Chartres and St. Ann Streets, New Orleans, La.

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Oesterreichischer Ingenieur- und Architekten-Verein, Eschenbachgasse 9, Vienna, Austria.

Oregon Society of Civil Engineers, Portland, Ore.

Pacific Northwest Society of Engineers, 312 Central Building, Seattle, Wash.

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Sociedad Colombiana de Ingenieros, Bogota, Colombia.

Sociedad de Ingenieros del Peru, Lima, Peru.

Societe des Ingenieurs Civils de France, 19 rue Blanche, Paris, France.

Society of Engineers, 17 Victoria Street, Westminster, S. W., London, England.

Svenska Teknologforeningen, Brunkebergstorg 18, Stockholm, Sweden.

Tekniske Forening, Vestre Boulevard 18–1, Copenhagen, Denmark.

Vermont Society of Engineers, George A. Reed, Secretary, Montpelier, Vt.

Western Society of Engineers, 1737 Monadnock Block, Chicago, Ill.

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DONATIONS*

RAILROAD VALUATION AND RATES.

By Mark Wymond. Cloth, 8 x 5½ in., illus., 339 pp. Chicago, Wymond & Clark, 1916. $1.50. (Donated by the Author.)

The preface states that this book is intended primarily as a treatise on the Principles of Rates and their relation to Valuation and Rate Regulation. In the first four chapters the author, it is said, has given an historical statement of facts relating to the railroads of the United States, and has discussed their promotion and construction in so far as such promotion and construction relate to capitalization and to the principles of rates and rate-making. The remainder of the book is devoted, it is said, to a discussion of the various phases of valuation and rates. The author, it is stated, has had thirty years experience in connection with the promotion, construction, reconstruction, operation, and valuation of railroads as an engineer in the service of railroad corporations, banking institutions, local communities, industrial and mining corporations, and of a traffic association, and it is hoped that this experience may give assurance to the reader as to his impartial attitude in his statements of essential facts on the subject, as contained in this book. The Contents are: Historical; Promotion; Construction-Reconstruction; Capitalization; Valuation; Rates; Rate Regulation.

IRRIGATION MANAGEMENT:

The Operation, Maintenance, and Betterment of Works for Bringing Water to Agricultural Lands. By Frederick Haynes Newell, M. Am. Soc. C. E. Cloth, 7¾ x 5¼ in., illus., 13 + 306 pp. New York and London, D. Appleton and Company, 1916. $2.00.

This book, it is stated in the preface, is an attempt to bring together, in concise form, the working ideas resulting from numerous conferences held during the past few years by members of the United States Reclamation Service and others interested in solving the problem of the proper utilization of irrigation systems after they are built and of obtaining fair returns from the irrigated land. The author has also endeavored, it is said, to answer the questions asked by irrigation managers, their assistants, and others connected with such work, with the hope of bringing about a greater degree of efficiency and economy in the operation, maintenance, and betterment of irrigation works. The general subject of irrigation and of methods of construction are not discussed herein, it is stated, because the technical side of the question has already been fully covered in other books. The early chapters of this volume were first published as separate articles in various engineering publications, and free use has also been made, it is said, of the informal reports, and particularly of the "Use Book", of the United States Reclamation Service in the compilation of the latter chapters. The Chapter Headings are: The Problems; The Physical Conditions; The Human Element; The Legal Side; Operation Organization; Methods of Operation; Records and Schedules; Water Economy; Maintenance; Expenditures, Recording and Classifying; Receipts and Values; The Irrigator and His Associations; Methods of Applying Water; The Products; Conclusions; Index.

GENERAL SPECIFICATIONS FOR CONCRETE BRIDGES.

By Wilbur J. Watson, M. Am. Soc. C. E. Third Edition. Paper, 11 x 8½ in., illus., 70 pp. Cleveland, Ohio, The Author, 1916. $1.00. (Donated by The McGraw-Hill Book Company, Inc.).

The first edition of these specifications was published in 1908 and the second in 1910, and in order to have this, the third, edition conform to present practice radical changes in the requirements, especially in those sections devoted to quality of materials, have been made. The greatest advancement, it is stated, has been in those branches covered by the sections on Surface Finish and Waterproofing, and these sections have been entirely rewritten. The specifications are intended and have been used, it is stated, by designing engineers for railroad, municipal, and county purposes and also as a standard for the preparation and comparison of competitive designs, and the author hopes that, as the value of concrete and reinforced concrete as

*Unless otherwise specified, books in this list have been donated by the publishers.

materials of construction have been firmly established, a careful observance of specifications such as are herein presented will reduce the troubles and failures heretofore encountered in their use and lead to the careful design, selection of materials, and construction necessary to their success. The Contents are: Definitions, Classification and Loads; Rules for Computing and Designing; Working Unit Stresses; Formulas; Quality of Materials for Concrete Work; Proportioning, Mixing and Placing Concrete; Requirements for Placing Reinforcing Steel, Inserts, etc.; Placing Concrete in Cold Weather; Forms and Centers; Surface Finish; Waterproofing; Reinforced Steel Construction; Cast Stone and Blocks; Concrete Piling; Inspection and Tests; Retaining Walls, Abutments, Piers, etc.; Concrete Arches; Reinforced Concrete Slabs, Beams, Girders, Columns and Trusses; Foundations and Footings; Timber Piling; General; Cement Walks, Concrete Curbs and Roadways; Brick Pavement; Asphalt Block Pavement; Sheet Asphalt Pavement; Wood Block Pavement; Bituminous Pavement.

PARKS AND PARK ENGINEERING.

By William T. Lyle, Assoc. M. Am. Soc. C. E. Cloth, 9¼ x 6 in., illus., 8 + 130 pp. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Limited, 1916. $1.25.

Although the conception and design of a park system is the function of the landscape architect, the execution of his general plans, as well as the design of the engineering features, belongs, it is stated, to the engineer. The park engineer must be proficient, it is said, in matters pertaining to the acquisition of lands, surveying, earth excavation, masonry, road construction, under-drainage, sewerage, water supply, lighting, and bridge construction, all of which subjects are discussed in this book specifically in relation to park construction. There is also a chapter on Labor and Contracts which, it is said, will be found especially useful by city officials. The volume is intended, it is stated, for the young and inexperienced engineer of construction, but the author hopes that it will be of use to members of park associations and commissions, and by engineers and others engaged in the development of park systems and private estates. The Contents are: Desirability and Acquisition of Parks; Lands and Surveys; Design; Labor and Contracts; Construction; Index.

EARTH PRESSURE, RETAINING WALLS AND BINS.

By William Cain, M. Am. Soc. C. E. Cloth, 9¼ x 6 in., illus., 10 + 287 pp. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Limited, 1916. $2.50.

Coulomb was the first (1781), it is said, to formulate laws of friction and cohesion affecting masses of earth, and although these laws seem to have been verified by many experiments, as has been pointed out by the author in Chapter I, nevertheless, it is stated, more experiments on every kind of earth are still necessary for complete confidence. In Chapters II and III, therefore, the theory of earth devoid of cohesion is fully developed by both the graphical and analytical methods for such granular materials as clean, dry sand, gravel, and rip-rap, and in Chapter IV, the author has made numerous applications of such theory to the design of retaining walls of stone and reinforced concrete. Chapter V is devoted to earth pressures in coherent earth, surfaces of rupture, stable slopes, foundations, thrust against a retaining wall, bracing of trenches and the pressures on tunnel linings, and there is also included an independent graphical method for evaluating earth thrust. In Chapter VI, the theory of deep bins is discussed, and the author, it is said, has attempted to reach fairly good results relative to thrusts on the walls of shallow bins filled with coal. An approximate solution of stresses in wedge-shaped reinforced concrete beams is given in Appendix I, with diagrams to facilitate computation, and in Appendix II, a discussion of the results of experiments on model retaining walls is included. The Chapter headings are: Laws of Friction and Cohesion, Tables, Direction, and Distribution of Stress; Thrusts of Non-Coherent Earth, Graphical Methods; Non-Coherent Earth, Analytical Methods; Designing Retaining Walls of Stone or Reinforced Concrete; Coherent Earth; Bin Theory; Appendix I, Stresses in Wedge-Shaped Reinforced Concrete Beams; Appendix II, Discussion of Experiments on Model Retaining Walls; Index.

AMERICAN CIVIL ENGINEERS' POCKET BOOK.

By Mansfield Merriman, Editor-in-Chief; Messrs. Ira O. Baker, Arthur H. Blanchard, Charles B. Breed, Walter J. Douglas, Louis A. Fischer, George A. Goodenough, Frederic R. Harris, Allen Hazen, Frank P. McKibben, Edward R. Maurer, Rudolph P. Miller, Alfred

Noble, Frederick E. Turneaure, Walter Loring Webb, and Gardner S. Williams, Associate Editors. Third Edition, Enlarged. Leather, 7 x 4¼ in., illus., 9 + 1 571 pp. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Limited, 1916. $5.00.

When this Pocket Book was first published in 1911, the editors were told, it is stated, that they must select topics of interest to civil engineers, they must condense all matter and still present it clearly, and that the Pocket Book must be better and fuller than any published in the English language. These instructions were followed and the Pocket Book has become, it is stated, the chief reference work for the Profession. In this the third edition, in addition to the revision and re-setting of more than 50 pages of the second edition and the numerous other additions and changes made to bring the subject-matter up to date, a new section of 96 pages has been included, covering Harbor and River Works, by Frederic R. Harris, M. Am. Soc. C. E., Corps of Civil Engineers, U. S. Navy. The Index has also been revised and re-set, and the book now contains 41 articles, 31 tables, 103 drawings, and 120 pages more than the second edition. The Contents are: Mathematical Tables, by Mansfield Merriman; Surveying, Geodesy, Railroad Location, by Charles B. Breed; Steam and Electric Railroads, by Walter Loring Webb; Materials of Construction, by Rudolph P. Miller; Plain and Reinforced Concrete, by Frederick E. Turneaure; Masonry, Foundations, Earthwork, by Ira O. Baker; Masonry and Timber Structures, by Walter J. Douglas; Steel Structures, by Frank P. McKibben; Hydraulics, Pumping, Water Power, by Gardner S. Williams; Water Supply, Sewerage, Irrigation, by Allen Hazen; Dams, Aqueducts, Canals, Shafts, Tunnels, by the late Alfred Noble and Silas H. Woodard; Mathematics and Mechanics, by Edward R. Maurer; Physics, Meteorology, Weights and Measures, by Louis A. Fischer; Steam and Electric Engineering, by George A. Goodenough and F. Malcolm Farmer; Highway Engineering, by Arthur H. Blanchard; Harbor and River Works, by Frederic R. Harris; Index, by Clinton L. Bogert.

COST ACCOUNTING: THEORY AND PRACTICE.

By J. Lee Nicholson. Second Printing. (Ronald Accounting Series.) Three-quarters Morocco, 9 x 6 in., illus., 341 pp. New York, The Ronald Press Company, 1916. $4.00.

This volume, the preface states, is not presented as a reference book dealing with factory organization and efficiency methods, nor as presenting all that could be said on the subject of costs, the author's main purpose, it is said, being (1), to provide for the public and cost accountant a reference book dealing directly with the practical parts of cost accounting; (2) to present simply and directly, to the student, the principles and methods of cost accounting; and (3) to furnish the manufacturer with a work containing all the important practical points in connection with cost accounting, summarized aud briefly explained. The Chapter headings are: Cost Finding and Its Functions: Elements of Costs; Interest in Its Relation to Cost; Principles and General Methods of Cost Finding; Methods of Distributing Indirect Expenses; Wage Systems; Recording the Material and Labor Costs; Compiling the Cost Data; Control of the Cost Records by the Financial Records; The Examination of a Plant; Devising a Cost System; Estimating Cost Systems; Departmental Systems; Special Order System Based on the Productive Labor Method; Special Order System Based on the Process or Machine Method; Product System on the Productive Labor Method; Product System Based on the Machine or Process Method; Forms Relating to Material; Production Orders and Requisitions; Time Reports and Pay-Roll Forms; Summaries of Production and Cost; Forms Relating to Finished Product; Sales and Financial Records; Index.

VALUE FOR RATE-MAKING.

By Henry Floy, M. Am. Soc. C. E. Cloth, 9¼ x 6¼ in., illus., 8 + 322 pp. New York and London, McGraw-Hill Book Company, Inc., 1916. $4.00.

The preface states that notwithstanding the fact that much has been done toward defining the methods to be used and standardizing valuation procedure, various and conflicting views are still held by different authorities relative to the principles involved in determining a basis of value for rate-making. The author's purpose in this book, it is said, has been to emphasize further at least three principles which seem to him to be essential in determining a fair value for rate-making, namely, fair present value of the property used, deduction for absolute depreciation only, and the valuation of non-physical as well as physical parts of a property. There is included, it is stated, much matter that was originally prepared for the discussion of papers before engineering societies and for legal briefs and cases for presentation before Courts and Commissions, and it is hoped that, as a whole, the book will present an orderly logical argument for the principles involved. The Contents are: Introduction; Definitions; Fundamentals in Valuation; Fair Value for Rate-Making; Cost of Reproduction; Land, Paving and Water Rights; Franchises, Working Capital and Bond Discounts; Going Value; Depreciation; Index.

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Building Construction and Superintendence. By F. E. Kidder. Pt. 2, Carpenters' Work. Ninth Edition, Revised, Rewritten and Enlarged, by Thomas Nolan. Pt. 3, Trussed Roofs and Roof Trusses. Third Edition. New York, 1915.

Diemaking and Die Design: A Treatise on the Design and Practical Application of Different Classes of Dies for Blanking, Bending, Forming and Drawing Sheet-Metal Parts, Including Modern Diemaking Practice and Fundamental Principles of Die Construction. Compiled and Edited by Franklin D. Jones. New York, 1915.

Aircraft in Warfare: The Dawn of the Fourth Arm. By F. W. Lanchester. London, 1916.

The Rise of Rail-Power in War and Conquest, 1833-1914, With a Bibliography. By Edwin A. Pratt. London, 1915.

The New International Year Book: A Compendium of the World's Progress for the Year 1915. Frank Moore Colby, Editor, Allen Leon Churchill and Horatio S. Krans, Associate Editors. New York, 1916.

R. L. Polk & Co.'s Trow General Directory of New York City, Embracing the Boroughs of Manhattan and the Bronx, 1916. New York.

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By purchase	7
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WOLF, ALBERT MATTHIAS. Prin. Asst. Engr., Condron Co., Chicago (Res., 902 Eighteenth Ave., Melrose Park), Ill.		April 18, 1916
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JUNIORS	Date of Membership.
ALLEN, HERSCHEL HEATHCOTE. Asst. Bridge Engr., State Roads Comm., Towson, Md.	Nov. 3, 1915
ARAKAWA, FUTOSHI. Hilo, Hawaii	Nov. 3, 1915
BENHAM, CLAUDE GILBERT. Asst. Engr., Virginia Ry. & Power Co., 800 Park Ave., Norfolk, Va.	April 18, 1916
BOWNE, SIDNEY BREESE. Cons. Engr. and San. Expert (Walter E. Sexton Co.); Engr., Village of Mineola, Mineola, N. Y.	April 18, 1916
DIEHL, WILLIAM CHARLES. Care, Ferrocarril del Pacifico, Cali, Colombia	Aug. 31, 1915
DOUGHERTY, EDWARD JAMES. South Baltimore, Curtis Bay P. O., Md.	April 18, 1916
HOLMBOE, LAWRENCE SCOFIELD. Contr. and Engr. (The Holmboe Co.), 311 Majestic Bldg., Oklahoma, Okla.	April 18, 1916
MCKEAN, ALEXANDER MATTHEWS. Instrumentman, Providence Water Supply Board, 50 East Manning St., Providence, R. I.	April 18, 1916
SMITH, HERSCHEL C. Instr., Civ. Eng., Univ. of Oklahoma, 524 South Webster Ave., Norman, Okla.	April 18, 1916
WEAVER, FRANK LLOYD. Instr. in Civ. Eng., Johns Hopkins Univ., Station N, Baltimore, Md.	April 18, 1916

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REINSTATEMENTS

MEMBERS	Date of Reinstatement.
SCAMMELL, JOHN KIMBALL	April 18, 1916

RESIGNATIONS

MEMBERS	Date of Resignation.
GARRISON, EVERETT	Dec. 31, 1915

ASSOCIATE MEMBERS	Date of Resignation.
FRANCIS, WILLIAM	April 18, 1916

JUNIORS	
SHERWOOD, WAKEMAN FRANCIS	April 18, 1916

DEATHS

ENGSTRÖM, FRANS. Elected Associate Member, May 4th, 1892; died March 20th, 1916.

HOLBROOK, FREDERICK WILLIAM DOANE. Elected Member, October 6th, 1886; died April 13th, 1916.

NEELY, WILLIAM RIDLEY. Elected Member, July 9th, 1906; died April 11th, 1916.

PRESTON, CHARLES HENRY. Elected Member, October 5th, 1909; died April 20th, 1916.

Total Membership of the Society, May 4th, 1916,

7 925.

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(April 3d, to May 1st, 1916)

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In the subjoined list of articles, references are given by the number prefixed to each journal in this list:

(2) *Proceedings*, Engrs. Club of Phila., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Chicago, Ill., 50c.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Gesundheits Ingenieur*, München, Germany.
(8) *Stevens Institute Indicator*, Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, 432 Fourth Ave., New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *Engineering Record*, New York City, 10c.
(15) *Railway Age Gazette*, New York City, 15c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Electric Railway Journal*, New York City, 10c.
(18) *Railway Review*, Chicago, Ill., 15c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 20c.
(21) *Railway Engineer*, London, England, 1s. 2d.
(22) *Iron and Coal Trades Review*, London, England, 6d.
(23) *Railway Gazette*, London, England, 6d.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *Railway Mechanical Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England, 4d.
(27) *Electrical World*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal*, Royal Society of Arts, London, England, 6d.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium, 4 fr.
(31) *Annales* de l'Assoc. des Ing. Sortis des Ecoles Spéciales de Gand, Brussels, Belgium, 4 fr.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France, 1 fr.
(34) *Portefeuille Economiques des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
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(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(39) *Technisches Gemeindeblatt*, Berlin, Germany, 0, 70m.
(40) *Zentralblatt der Bauverwaltung*, Berlin, Germany, 60 pfg.
(41) *Electrotechnische Zeitschrift*, Berlin, Germany.
(42) *Proceedings*, Am. Inst. Elec. Engrs., New York City, $1.
(43) *Annales des Ponts et Chaussées*, Paris, France.
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(48) *Zeitschrift*, Verein Deutscher Ingenieure, Berlin, Germany, 1, 60m.
(49) *Zeitschrift für Bauwesen*, Berlin, Germany.
(50) *Stahl und Eisen*, Düsseldorf, Germany.
(51) *Deutsche Bauzeitung*, Berlin, Germany.
(52) *Rigasche Industrie-Zeitung*, Riga, Russia, 25 kop.
(53) *Zeitschrift*, Oesterreichischer Ingenieur und Architekten Verein, Vienna, Austria, 70h.
(54) *Transactions*, Am. Soc. C. E., New York City, $12.
(55) *Transactions*, Am. Soc. M. E., New York City, $10.

(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $6.
(57) *Colliery Guardian*, London, England, 5d.
(58) *Proceedings*, Engrs.' Soc. W. Pa., 2511 Oliver Bldg., Pittsburgh, Pa., 50c.
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(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *Steel and Iron*, Thaw Bldg., Pittsburgh, Pa., 10c.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 5c.
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(68) *Mining Journal*, London, England, 6d.
(69) *Der Eisenbau*, Leipzig, Germany.
(71) *Journal*, Iron and Steel Inst., London, England.
(71a) *Carnegie Scholarship Memoirs*, Iron and Steel Inst., London, England.
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(91) *Transactions*, Soc. Naval Archts. and Marine Engrs., New York City.
(92) *Bulletin*, Soc. d'Encouragement pour l'Industrie Nationale, Paris, France.
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(109) *Journal*, Boston Soc. C. E., Boston, Mass., 50c.
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(111) *Journal of Electricity, Power and Gas*, San Francisco, Cal., 25c.
(112) *Internationale Zeitschrift für Wasser-Versorgung*, Leipzig, Germany.
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Rock Drilling with Deep Hole Wagon Rigs Show Speed at Low Cost.* Charles A. Hirschberg. (14) Apr. 29.
Können mit Rücksicht auf die neuesten sprengtechnischen Erfahrungen Distanzerleichterungen bei Anlage unterirdischer Sprengmittelmagazine gewährt werden? Rudolf Feuchtinger. (115) Feb. 10.

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A Proposed Code of Ethics for the Western Society of Engineers. (4) Jan.
Regulation of Public Utilities. Leonard A. Busby. (4) Jan.
Temperature Inversions in Relation to Frost.* Alexander McAdie. (From *Annals* of the Astronomical Observatory of Harvard Coll.) (19) Feb. 26.
Our Modern Engineering Education. Edward Orton, Jr. (Paper read before the Ohio State Univ.) (19) Mar. 4.
Business in Engineering. F. G. Hatch. (Paper read before the Junior Institution of Engrs.) (47) Serial beginning Mar. 17.
Extraction of Benzol and Toluol by American Gas Oil and Green Oil. John Bond and Hubert Pooley. (Paper read before the Midland Assoc. of Gas Engrs. and Mgrs.) (66) Mar. 28.
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The Attitude of the Employer Towards Accident Prevention and Workmen's Compensation. W. H. Cameron. (55) Apr.
Modern Movement for Safety from Standpoint of Manufacturer. Melville W. Mix. (55) Apr.
How to Increase Factory Efficiency.* O. M. Becker. (9) Apr.
The Technical Production of Hydrogen and Its Industrial Application. Harry L. Barnitz. (105) Apr. 1.
Potash from Kelp in Southern California. H. L. Glaze. (105) Apr. 1.
Depreciation as an Element in Rate Making. Jared How. (From Arguments before the California Railroad Comm.) (24) Apr. 3.
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Coal Tar; Its Development and Uses. Arno C. Wilke. (Paper read before the Wisconsin Gas Assoc.) (24) Apr. 17.
Methods for Dealing with Arsenical Sulphuric Acid in the Manufacture of Sulphate of Ammonia.* P. Parrish. (66) Apr. 18.
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L'Enseignement doit Avoir pour But Exclusif la Formation de l'Esprit.* Henry Le Chatelier. (92) Jan.

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Road and Concrete Materials. H. S. Mattimore. (36) Mar.
Economics of Highway Engineering. L. I. Hewes. (36) Mar.
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Building Brick Roads Minus the Sand Cushion.* (76) Apr. 4.
Costs of Concrete Roads in the United States in 1914. (86) Apr. 5.
An Unusual Application of the Rattler Test for Paving Bricks.* F. L. Roman. (86) Apr. 5.
Comparative Costs of Hauling Gravel by Team and by Tractor for Road Work. O. L. Kipp. (Paper read before the Minnesota Engrs. and Surveyors' Soc.) (86) Apr. 5.
The Road Situation and State Highway Department Plans in Illinois. Wm. W. Marr. (86) Apr. 5.
Putting Macadam Roads in the Permanent Class.* Daniel T. Pierce. (Abstract of paper read before the National Conference on Concrete Road Building.) (86) Apr. 5.
Curbs and Sidewalks; Some Practical and Aesthetic Considerations in Their Design and Location. M. E. Chamberlain. (Abstract of paper read before the Minnesota Surveyors' and Engrs.' Soc.) (86) Apr. 5.
An Analysis of the Advantages of Monolithic Brick Pavement.* Maurice B. Greenough. (Abstract of paper read before the Ohio Eng. Soc.) (86) Apr. 5.
Bituminous Roads. Robert C. Muir. (Paper read before the Conference on Road Construction.) (96) Apr. 6.
A Study of Cracks in a Concrete Roadway at Indiana University.* Ulysses S. Hanna. (Paper read before the Indiana Eng. Soc.) (86) Apr. 12.
Patrol System, Gang System and Combination Patrol and Gang System of Road Maintenance in Maryland. H. G. Shirley. (86) Apr. 12.
Methods of Fixing Curb and Sidewalk Grades at Street Intersections on Steep Gradients.* John Wilson. (Abstract of paper read before the Minnesota Eng. Soc.) (86) Apr. 12.
Bituminous Paving Plants. L. Kirschbaum. (96) Apr. 13.
Building and Maintaining Roads with Refined Tar. John S. Crandell. (Abstract of paper read before the Inter. Road Congress.) (96) Apr. 13.
Wood-Block Pavement is Improved by Traffic.* (13) Apr. 13.
City Planning by the Zoning System in the Bronx.* (13) Apr. 13.
Oiling on Earth Roads. B. H. Piepmeier. (*Bulletin 11*, Illinois State Highway Dept.) (19) Apr. 15.
36-Mile Concrete Road Built by Day Labor will Link Canadian Cities.* H. S. Van Scoyoc. (14) Apr. 15.
Experience with Bitumen Carpeted Concrete Pavement in Ann Arbor, Mich. Manly Osgood. (Paper read before the Michigan Eng. Soc.) (86) Apr. 19.
Federal Plan Commission's Report; Government Receives Recommendations Looking Toward the Creation of a Truly Imposing Capitol (Ottawa, Canada).* *Sir* Thomas White. (From Report to Parliament.) (96) Apr. 20.
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Rational Method of Selecting Types Evolved for a Comprehensive County Road System.* William W. Marr. (14) Apr. 22.
Method and Cost of Constructing Concrete Service Test Road at Philadelphia, Pa. William H. Connell. (Abstract from Annual Report.) (86) Apr. 26.
Bronx Borough Makes its Own Asphalt Repairs, Effects Big Saving.* (14) Apr. 29.
New Device Measures Wear on Concrete Roads.* (14) Apr. 29.

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Light-Weight Interurban Cars.* R. W. Palmer. (17) Apr. 1.
Motors and Phase Converters on the N. & W. Locomotives.* J. V. Dobson. (17) Apr. 1.
Electric Operation on the C., M. & St. P.* (17) Apr. 1; (15) Apr. 28.
Suburban Coaches for the Grand Trunk Ry.* James Coleman. (18) Apr. 1.
Improvement in Passenger Car Construction and Design.* K. F. Nystrom. (Paper read before the Canadian Ry. Club.) (18) Apr. 1; (25) Apr.
The Necessity for Improved Systems at Railway Terminals. A. Jackson Marshall. (18) Apr. 1.
Trend of Tractive Power and Results on Fuel Costs, Ten Years' Record, 1904-1914, on Roads Whose Average Tractive Power per Locomotive in 1914 was Fifteen Tons or More. (18) Apr. 1.
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Railway Development in Japan. (23) Serial beginning Apr. 7.
Car Loading on the International & Great Northern Ry. (18) Apr. 8.
Operation of the P. R. R., Philadelphia-Paoli Electrification.* F. G. Grimshaw. (17) Apr. 8.
Use of Ampere-Hour Meter and Results Obtained by Chicago & Joliet Electric Railway. J. B. Tinnon. (Paper read before the Illinois Elec. Ry. Assoc.) (17) Apr. 8.
Electric Switching Locomotives for the C., M. & St. P. Ry.* L. C. Josephs. (18) Apr. 8.
Commission's Report on the Wreck at Milford, Conn. (18) Apr. 8.
Investigation of Initial Strains in Steel Rails.* (Report of the Interstate Commerce Comm.) (18) Apr. 8.
Unique Way of Handling Railroad Scrap.* F. L. Prentiss. (20) Apr. 13.
Concreting Soft Spots in Railway Roadbed. (13) Apr. 13.
Empty and Load Freight Brake Equipment.* Walter V. Turner. (Abstract of paper read before the St. Louis Ry. Club.) (15) Apr. 14.
A New Cut-Off on the Norfolk & Western.* (15) Apr. 14.
A Less-Than Carload Clearing House.* Henry A. Goetz. (15) Apr. 14.
New Lehigh Valley Roundhouse at Sayre, Pa.* (15) Apr. 14.
Europe Struggling with a Ship and Car Shortage.* (23) Apr. 14.
Location of Passing Sidings on Single Track.* F. L. Dodgson. (Paper read before the Railway Signal Assoc.) (23) Apr. 14.
Eliminating a Group of Nine Grade Crossings on the Long Island R. R. William L. Selmer. (18) Apr. 15.
Power Saving in Car Operation. E. S. Gillette. (Paper read before the Illinois Elec. Ry. Assoc.) (17) Apr. 15.
New All-Steel Cars for the Wilkesbarre & Hazleton Railway.* (17) Apr. 29.
New Tie-Treating Plant on the Northwestern Railway.* L. J. Putnam. (13) Apr. 20.
Recent Developments in Roadbed Drainage on Pennsylvania.* W. F. Rench. (15) Apr. 21.
Scientific Landscape Gardening on Railroads.* I. T. Worthley. (15) Apr. 21.
Recent Examples of 2-10-2 Type Locomotives.* (15) Apr. 21.
Covering a Rock Cut with Gunite, New York Central.* N. W. McCallum. (15) Apr. 21.
Raising the Grade on a High Embankment, Methods of Handling Traffic and Overcoming Slides in Enlarging the Approach Fill for the Bridge at Sibley, Mo.* (15) Apr. 21.
Long and Short Wheel Base Test Cars.* C. A. Briggs. (Paper read before the National Assoc. of Scale Experts.) (15) Apr. 21.
A Small Railroad Station that Pleases the Eye; Mountain Station, South Orange, the Delaware, Lackawanna & Western Railroad.* (14) Apr. 22.
A Study of a Corrugated Rail.* Henry M. Sayers. (17) Apr. 22.
Experiments in Magnetic Determination of Inhomogeneities in Steel Rails.* Charles W. Burrows. (*Scientific Paper No. 272*, Bureau of Standards.) (18) Apr. 22.
Designing a Scale to Order.* Eugene Motchman. (18) Serial beginning Apr. 22.
The Preparation of Stoker Coal.* (15) Apr. 28.
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Zweckmässigkeit und Wirtschaftlichkeit des Eisenbeton bei den Bauten der Eisenbahnen. (102) Serial beginning Feb. 15.

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The Cleveland Street Railway Situation. F. W. Doolittle. (115) Mar.
Notes on the Maintenance of Rolling Stock on the London Underground Railways.* (26) Mar. 24.
Emergency Snow-Fighting Equipment.* W. G. Murrin. (17) Apr. 1.
Boston Elevated Reports on Safety.* (17) Apr. 1.
Concrete Street Railway Track Foundation Constructed by Penetration, Baltimore, Md.* R. Keith Compton. (Abstract of paper read before the Am. Road Builders' Assoc.) (86) Apr. 5.
Steep Grade on San Francisco Street Railway Overcome.* (13) Apr. 6.
Economy of Power Consumption in Car Operation.* G. T. Seely. (Paper read before the Illinois Elec. Ry. Assoc.) (17) Apr. 8.
Car-Operating Efficiency.* J. F. Layng. (Paper read before the Illinois Elec. Ry. Assoc.) (17) Apr. 8.
The Brooklyn Articulated Car.* (17) Apr. 8.
An Inexpensive Steel Pole Line.* W. K. Palmer. (17) Apr. 8.
Co-operative Education in Electric Railway Work.* A. M. Wilson. (17) Apr. 15.
Contact Signals for Jamestown, N. Y., Lines.* (17) Apr. 15.
Safety a Real Economy in Columbus.* (17) Apr. 22.
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Factors Affecting Durations of Stop.* D. D. Ewing. (17) Apr. 22.
Portable Testing Apparatus Arranged for One-Man Operation.* E. D. Ransom. (17) Apr. 29.
Progress in Car Equipment Lubrication.* Alfred Green. (Abstract of paper read before the Am. Elec. Ry. Assoc.) (17) Apr. 29.
Nachrücksignale auf der Berliner Hoch-und Untergrundbau.* Bothe. (14) Mar. 30.

Sanitation.

Ventilation Requirements and Test Methods. E. V. Hill. (4) Feb.
The Calorimeter as the Interpreter of the Life Processes: a Study of the Fuel Requirements of the Human Individual. Graham Lusk. (Paper read before the National Academy of Sciences.) (19) Mar. 11.
Modern Concrete Sewers and Other Structures.* (19) Mar. 11.
Essence of Laws Governing Stream Pollution in the United States. Le Roy K. Sherman. (From *Bulletin No. 16,* Rivers and Lakes Comm. of Illinois.) (86) Mar. 29.
Municipal Sewer Construction in Moose Jaw, Saskatchewan. (60) Apr.
The Latest Method of Sewage Treatment. Edward Bartow. (109) Apr.
Burning Salt-Glazed Sewer Pipe. George D. Morris. (Paper read before the Am. Ceramic Soc.) (76) Apr. 4.
Trial Activated-Sludge Unit at Cleveland, Ohio.* R. Winthrop Pratt. (13) Apr. 6.
Hints on the Construction of Vitrified Clay Segment Block Sewers. J. M. Egan, Jr. (Paper read before the Illinois Soc. of Engrs. and Surveyors.) (96) Apr. 6.
Warm-Air Furnace Supersedes Fireplace Heater.* Tinquill. (101) Apr. 7.
Plumbing Work in Pittsburgh Comfort Station.* (101) Apr. 7.
Give Conclusions on Activated Sludge Tests. (14) Apr. 8.
Disposal of Gas House Wastes.* Paul Hansen. (Paper read before the Illinois Gas Assoc.) (24) Apr. 10.
The Circulating Tank Water Heater.* E. S. Stack. (Paper read before the Newton and Watertown Gas Light Co.) (24) Apr. 10.
The Cause, Amount and Restriction of Infiltration of Ground Water Into Sewers. Charles P. Chase. (Paper read before the Iowa Eng. Soc.) (86) Apr. 12.

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Sewage-Works Construction at Dallas, Tex. (13) Apr. 13.
Unit Concrete Construction for Manholes, Vaults and Catch Basins at St. John, N. B.* R. Fraser Armstrong. (96) Apr. 13.
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An Indirect and Direct Hot-Water System.* (101) Apr. 14.
Heating and Ventilating a School by Electricity.* (101) Apr. 14.
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Heating of Dynamite Thaw Houses.* (101) Apr. 14.
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Hot-Water and Steam Heating. Ira N. Evans. (64) Serial beginning Apr. 18.
Four Years' Experience in Mosquito Extermination at Philadelphia. William H. Connell. (From Report to the City of Philadelphia.) (86) Apr. 19.
The Treatment of Colliery and Other Trade Wastes in the Emscher District. Kenneth Allen. (86) Apr. 19.
5-Ton Garbage Reduction Plant Yields Profit to City. George R. Bascom. (14) Apr. 22.
Tests of Effect of Method of Bedding Upon the Supporting Strength of Drain Tile and Sewer Pipes.* N. J. Schlick. (Paper read before the Iowa Drainage Assoc.) (86) Apr. 26.
Winter Experience with the Activated Sludge Process of Sewage Treatment at Milwaukee—Sludge Disposal. William R. Copeland. (Paper read before the Am. Chemical Soc.) (86) Apr. 26.
Experiences in the Application of the Activated Sludge Process to Chicago Stockyards Sewage. Arthur Lederer. (Paper read before the Am. Chemical Soc.) (86) Apr. 26.
Status of Activated-Sludge Sewage Treatment.* George T. Hammond. (13) Apr. 27.
Milwaukee Activated Sludge Investigations.* R. O. Wynne-Roberts. (96) Apr. 27.
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The Use of Hydrated Lime in Concrete. H. E. Weidemann. (115) Mar.
Handling Concrete in Building Operations. (19) Mar. 11.
Protection Against Lightning.* O. S. Peters. (From *Technologic Paper No. 56*, Bureau of Standards.) (19) Mar. 18.
Some Examples of Dangerous Structures. W. G. Perkins. (Abstract of paper read before the Concrete Inst.) (104) Mar. 24.
The Vibrocel System of Construction. (23) Mar. 24.
The Decay of Metals.* Cecil H. Desch. (Abstract of paper read before the Institution of Engrs. and Shipbuilders in Scotland.) (47) Mar. 24.
The Cumberland Electrolytic Method of Preventing Corrosion.* J. F. Peter. (Paper read before the Inst. of Metals.) (11) Mar. 31; (22) Mar. 31.
Results of Some Tests to Determine the Distribution of Vertical Pressure Through Sand.* R. B. Fehr and C. R. Thomas. (Abstract from *Bulletin No. 8*, Pennsylvania State Coll.) (86) Mar. 29.
Design and Construction Features of a Reinforced Concrete Hotel Building at Lake Louise, Alberta, Canada.* William Wren Hay. (86) Mar. 29.
The Electrolytic Method of Preventing Corrosion.* Elliott Cumberland. (Paper read before the Inst. of Metals.) (11) Mar. 31; (22) Mar. 31.
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Illumination of Oakland's Auditorium.* Romaine W. Myers. (111) Apr. 1.
Beams without Lateral Support. R. Fleming. (13) Apr. 6.
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Painting by Dipping, Spraying and Other Mechanical Means. Arthur Seymour Jennings. (29) Apr. 7.
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The New Chemistry Buildings of University College, London.* F. M. Simpson. (11) Apr. 7.
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Exhibition Testing of Concrete. Donald A. Thomas. (13) Apr. 13.
Influence of Thickness on Tensile Tests.* G. B. Waterhouse. (20) Apr. 13.
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Portable Concrete Plant Builds Louisville and Portland Canal Wall.* (14) Apr. 15.
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How to Estimate Brick and Hollow-Tile Masonry. (76) Apr. 18.
Designing Compression Members for Small Stresses. Albert Smith. (Abstract of paper read before the Indiana Eng. Soc.) (86) Apr. 19.
Design and Construction of the Foundation for the Union National Bank Building, Cleveland, O.* R. B. Buettell. (From the *Wisconsin Engineer.*) (86) Apr. 26.
Hand Drills in Structural Work.* (13) Apr. 27.
Foam-System Installation for Fighting Oil Fires.* C. P. Bowie. (13) Apr. 27.
Portable Washer for Aggregates.* (13) Apr. 27.
Spruce Piles Cannot Stand Compacted Gravel.* Charles T. Main and Henry E. Sawtell. (13) Apr. 27.
Economy of Continuity in Reinforced Concrete.* Raymond J. Roark. (13) Apr. 27.
Three Reinforced-Concrete Buildings Alone Resist Flames in Paris, Texas, Fire.* (14) Apr. 29.
Tests of Hollow-Tile, Flat Arch Floor Slabs Show Effects of Concentrated Loads.* Clyde T. Morris. (14) Apr. 29.
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Die Berechnung eiserner Tragwerksteile auf Knickung. H. Nitzsche. (115) Feb. 17.
Der Waldfriedhof im "Rheinhard", Schaffhausen.* H. Schlatter. (107) Mar. 11.

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Precise Levelling by the Geodetic Survey.* F. B. Reid. (96) Serial beginning Apr. 20.

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Situation at Little Falls, New Jersey. F. W. Green. (59) Mar.
The Air Lift.* Arthur H. Ford. (59) Mar.
Sources of Water Pollution. John W. Hill. (59) Mar.
Filter Operation. S. M. Van Loan and Albert Tolson. (59) Mar.
The Development of Rapid Sand Filters in Ohio. Philip Burgess. (59) Mar.
Pneumatic Pumping as Applied to Municipal Plants.* John Oliphant. (59) Mar.
Earthing Electrical Systems to Water Pipes.* Burton McCollum and O. S. Peters. (59) Mar.
Methods of Sending Specimens of Water. Jack J. Hinman, Jr. (59) Mar.
Notes on Fire Protection. T. N. Hooper. (59) Mar.
Experiments in Water Softening with a Zeolite-Like Substance. Robert N. Kinnaird. (59) Mar.
Iron Removal by Rapid Sand Filtration.* Frank E. Hale. (59) Mar.
Water Softening Practice.* Samuel A. Greeley. (59) Mar.
Resanding Problems at Albany. G. E. Willcomb. (59) Mar.
Variations in Precipitation as Affecting Water Works Engineering.* Carl Peter Birkinbine. (59) Mar.
A Mercury Column Alarm for Standpipes.* W. E. Haseltine. (59) Mar.
Effect of Solutions of Filter Alum on Brass Pipe and Fittings. G. R. Spalding. (59) Mar.
Cleaning the Bayside Filters. E. G. Manahan. (59) Mar.
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Special Features of Four New Water Purification Plants in Indiana. John C. Diggs. (Paper read before the Indiana San. and Water Supply Assoc.) (86) Mar. 29.
The Prevention of Corrosion in Pipe Lines.* F. R. Speller. (Abstract of paper read before the Am. Soc. of Heating and Ventilating Engrs.) (47) Mar. 31.
Irrigation Pumping by Electric Power. Geo. D. Longmuir. (111) Apr. 1.
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More Trouble at Austin Dam.* (13) Apr. 6.
Wood Against Steel Pipe in Seattle Water-Works. John Lamb. (13) Apr. 6.
Valuation of Water Rights for Power Companies. J. P. Newell. (13) Apr. 6.
Water Supply of the City of St. John, N. B. R. Fraser Armstrong. (96) Apr. 6.
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The Water Supply of Melbourne.* (12) Serial beginning Apr. 7.
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Test Made of Model Weir.* Ben D. Moses. (14) Apr. 8.
Contractors Suggest Scheme for Subaqueous Pipe Line. Eliot N. Smith. (14) Apr. 8.
Utilization of Oregon's Latent Water-powers.* John H. Lewis. (111) Apr. 8.
Comparison of Wood and Concrete for Use in Irrigation Structures. S. T. Harding. (86) Apr. 12.
Methods and Costs of Concrete Lining Irrigation Laterals, Orland, Project, U. S. Reclamation Service. A. N. Burch. (From *Reclamation Record.*) (86) Apr. 12.
The Electric Pumping of Deep Wells at Memphis, Tenn. (86) Apr. 12.
California Rainfall and Runoff and Recent Floods. M. J. Bartell and R. P. Montreal.* (86) Apr. 19; (13) Apr. 27.
Water and Sewer Improvements at Madison, Wis.* (13) Apr. 13.
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* Illustrated.

PAPERS AND DISCUSSIONS

MAY, 1916

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INSTITUTED 1852

PAPERS AND DISCUSSIONS

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Vol. X' II. MAY, 1916. No. 5.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

THE PRESERVATION OF SANDY BEACHES IN THE VICINITY OF NEW YORK CITY

By Elliott J. Dent, M. Am. Soc. C. E.

To be Presented June 7th, 1916.

Synopsis.

The object of this paper is to set before the Society the result of the writer's study of the effect of wave action on the sandy beaches skirting the south shore of Long Island and the New Jersey shore north of Asbury Park, to call attention to the means by which improved beach property may be protected, and to emphasize the damage that must inevitably result to the beaches as a whole if the erection of structures that interfere with littoral drift is allowed to continue.

The paper treats of such subjects, only, as are considered of primary importance in the particular locality under consideration. It is subdivided into sections, and the contents and conclusions are described by sections:

Tidal Currents and Ocean Currents.—These currents are of no effect except in the vicinity of inlets, and receive only brief mention.

Waves.—The behavior of deep-sea and shallow-water waves prior to the plunge receives a brief mention. The phenomena accompanying the plunge, the up-rush and the back-wash of the wave, and the

NOTE.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

phenomena accompanying the undertow are discussed and illustrated in some detail.

The Origin of Beach Sand and Gravel.—A brief discussion is given, and the conclusion is reached that the principal source of such material is not the grinding up of cliffs, etc., but the sorting out of particular sizes from the soil formed by the decomposition of the primary rocks.

Typical Beach Forms.—Typical beach forms are discussed and illustrated, particular emphasis being placed on the distinction between the temporary berms and the more permanent dunes, etc.

Constructive and Destructive Power of Waves.—The transporting power of the up-rush, back-wash, and undertow are discussed. The conclusions are arrived at that wave action always causes a transfer of material from the beaches to deep water, that in the normal case berms are constructed during stormy weather and eroded by undermining during quiet weather.

Littoral Drift, and Jetties and Groins.—Littoral drift is described, and the effect thereon of inlets, jetties, and groins is discussed. The conclusions are reached that, for beaches such as those under consideration, inlets, jetties, and groins interfere with littoral drift and increase the quantity of material permanently lost to the beaches.

Bulkheads.—The proper functions of bulkheads and sea walls, their proper location with respect to the berms, and the absence of extensive erosion due to back-wash, are discussed. The conclusions are reached that such structures, when their strength is commensurate with their exposure, will afford a real protection to lands in their rear, that their existence will not prevent the formation of berms when other conditions are favorable, that if not placed too far seaward they will not interfere with littoral drift, and that when used to extend the uplands beyond their natural limits such structures may cause a serious loss to the beaches to their leeward.

The increasing value of ocean beach property has led many investors to build nearer and nearer the shore line, relying on the erection of shore-protection works to guard their investments against damage from the sea. Under-estimates of the forces to be resisted and over-estimates of the efficacy of certain types of shore-protection works have resulted in extensive property losses in the immediate vicinity of New York City. In view of the importance of such beach colonies as Coney Island, the Rockaways, and Long Beach, on the south shore of Long Island, and in view of the existence of similar colonies extending in a nearly continuous line along the New Jersey coast from Seabright to beyond Asbury Park, the writer has been tempted to prepare this paper, setting forth such of the general principles of beach formation and erosion as apply to these localities.

The first time he was required to report on plans for the protection of a portion of one of these beaches, he advocated the erection of a system of groins. The direction of the littoral drift was well established, and, in the literature on the subject, no doubt was expressed as to the efficacy of such structures "when properly designed". The case in point appeared to be so simple that the writer had no doubt as to his ability to design the structures properly.

Subsequently, the writer spent much of his time for two summers walking the beaches around New York City. Occasional beach trips were made during the winter, and certain beaches around San Juan, Porto Rico, with which the writer was familiar, were re-visited during the summers of 1914 and 1915. At the same time the literature on the subject was quite thoroughly examined. Memoranda made during these visits furnished the foundation of observed facts on which the discussion herein presented has been based.

There are certain general principles of wave and current action that apply to all beaches, but in one instance the controlling force may be very different from that in another. An effort will be made to state quite fully the principles in regard to the major forces at work on the sandy beaches around the entrance to New York Harbor. Some of the forces emphasized in this paper may be of little or no importance in some other particular locality; and phenomena which, in that other locality, may be of controlling importance may be entirely ignored in this paper. As an illustration, it may be stated that the problem of shore protection at the foot of the caving bluffs along the north shore of Long Island is totally different from that to be faced along the sandy beaches of the south shore; the latter is discussed in this paper.

Tidal Currents.

On an open coast, far away from any inlet, there is a semi-daily landward and a semi-daily seaward current. If the tide is rising at the rate of 1 ft. per hour, and if the mean depth is 1 ft. at a point 3 600 ft. off shore, there will be a shoreward current at that point having a mean velocity of 1 ft. per sec. As the slope of the foreshore, in the locality under consideration, is much greater than 1 in 3 600, the subject of currents due to the flood and ebb tides may be dismissed, except in the vicinity of inlets.

Ocean Currents.

The Gulf Stream directly east of the mouth of Chesapeake Bay has a surface velocity of about 2½ ft. per sec. If a steady current of equal velocity flowed along the New Jersey coast, in shallow water, with a loose sandy bottom, we might expect to find sand waves, deep pools, and shallow bars, all subject to frequent changes in position. Such conditions do not exist along the shores under consideration, and, so far as this paper is concerned, no discussion of ocean currents is necessary.

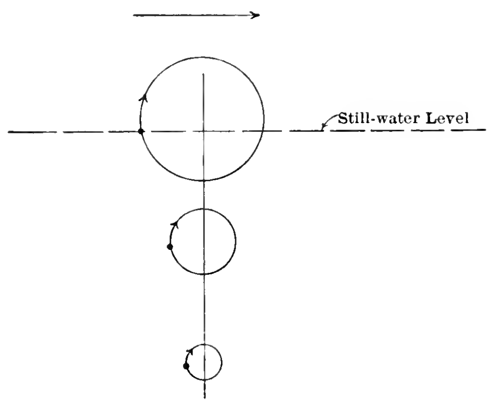

Fig. 1.—As a Deep-Water Wave Passes, Each Particle of Water Moves in a Circular Orbit; the Radii of the Orbits Decrease with Increased Depth Below the Surface; When the Wave has Passed, Each Particle is Left in Its Original Position.

Waves.

Wave action is an important factor in the construction or destruction of ocean beaches. A few of the general principles will be given here, and the reader may consult the various works on the subject if further information is desired. The writer has followed the paper "Wave Action in Relation to Engineering Structures".*

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* By the late Col. D. D. Gaillard, Corps of Engineers, U. S. Army, published as Professional Paper No. 31, Corps of Engineers, U. S. Army.

The form of a wave is normally that of a common or prolate cycloid. If we assume several filaments of water, parallel to the direction of travel of the wave, and at certain selected distances below the surface of the water, we shall find that there is no tendency of these filaments to cross as the wave passes by. The passage of a wave does not mix the surface water with the deeper water, or *vice versa.*

In deep water each particle of water coming within the influence of a wave moves in circular orbit. (Fig. 1.) The orbital velocity is uniform, and in the upper half of the orbit the motion is in the direction of wave travel. When the wave has passed, each particle is left in the position it occupied before the wave arrived. The radii of the orbits decrease with increases of depth below the surface.

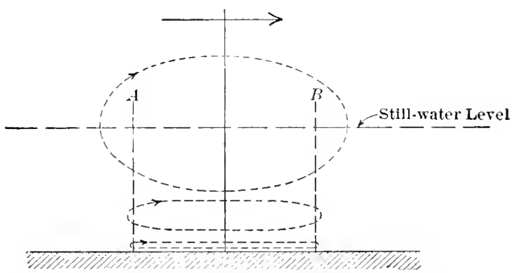

FIG. 2.—IN A SHALLOW-WATER WAVE, THE ORBITS OF THE VARIOUS PARTICLES OF WATER ARE ELLIPSES; THE FOCAL LENGTH OF ALL ORBITS IS A CONSTANT, *A B*; NEAR THE BOTTOM THE ORBITS APPROACH A STRAIGHT LINE AS A LIMIT; THE VELOCITIES ACCOMPANYING THE FORWARD AND BACKWARD SWINGS ARE EQUAL.

In shallow water (Fig. 2) the orbits are elliptical in form. The semi-axes of the orbits decrease with increases in depth below the surface, but the focal distance of all orbits is constant. The horizontal or major semi-axis approaches one-half of the focal distance as a limit. The vertical or minor semi-axis approaches zero as a limit. A particle of water very near the bottom moves in what is, to all intents and purposes, a straight line. It is important to note the orbital velocity of such particles.

If a circle is described, concentric with the elliptical orbit, and with a diameter equal to the major axis of the orbit; if a point moves along the circumference of the circle with a uniform velocity, such that the time required to complete the circle is the same as that required by the particle of water to complete its orbit, then the orbital velocity of the particle of water will be such that it will at all times lie vertically above or below the point on the circumference of the circle.

The orbital velocity of the particle of water is at a maximum as the trough or the crest of the wave passes over it. As the trough passes, the orbital motion is opposite in direction to the travel of the wave; as the crest passes, the orbital direction is with the wave travel. The velocities in the direction of wave travel and in the opposite direction are equal.

With a moderately sloping foreshore, deep sea waves approaching the beach are diverted in direction. The tendency is to change direction until the travel is perpendicular to the beach. Waves seldom strike the beaches under consideration at an angle of 45° from the perpendicular, or greater.

Assume for the moment that one is observing the effect of a heavy swell following a storm. In deep water a large rounded wave would be seen, its surface section corresponding approximately to the curve of a prolate cycloid; as the water becomes more shallow, the wave rises higher, becomes more pointed, and the section corresponds more closely to that of a common cycloid. When a certain depth is reached, the wave breaks and the upper point falls over, striking the front slope. Depending on the character of the bottom, the magnitude of the wave, etc., this first break may occur in depths exceeding 20 ft.

After the first break, a new wave is formed and travels shoreward until it in turn breaks when it reaches a certain depth. This process continues until water only a few feet in depth is reached, and then the wave breaks for the last time. (Fig. 3.)

This final break is called the plunge, and the point at which it occurs is called the plunge-point.* When the plunge takes place, orbital motion ceases, and a boiling, foaming, sheet of water rushes up the beach. This will be referred to as the up-rush. As the wave flows up the beach, the boiling diminishes until a relatively quiet sheet of water has been formed. When the kinetic energy has been entirely wasted, or transformed into potential energy, due to the increase in elevation, the back-wash begins, and the water flows down the slope in a smooth sheet. The velocity during this back-wash constantly in-

* The terms "plunge", "up-rush", and "back-wash" are borrowed from "Coast Erosion and Foreshore Protection", by John S. Owens and Gerald O. Case, Assoc. M. Am. Soc. C. E.

creases, and, except for a few feet near the upper margin, the back-wash has, in sand, a considerable transporting power.

On sandy beaches, the height of the wave at the time it reaches the plunge-point is not great. A height of 5 ft. is not infrequent, but the writer does not recall having seen breakers as high as 8 ft. The depth of water corresponding to the plunge is seldom more than 3 ft.

An after-effect of the plunge that requires special notice is the undertow. When the back-wash reaches a certain point, normally about the line of the still-water level, a new wave is encountered. The water from the earlier wave must find some escape to sea, and it is a matter of common knowledge that an off-shore current, hugging the bottom, is formed. This current is known as the undertow.

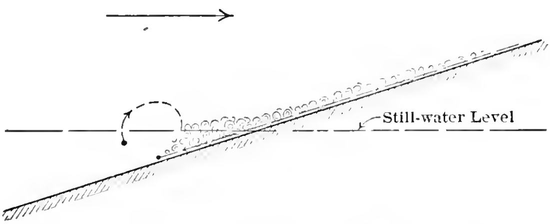

FIG. 3.—WHEN THE PLUNGE OCCURS, ORBITAL MOTION CEASES, AND A BOILING MASS OF WATER RUSHES UP THE BEACH; WHEN THE KINETIC ENERGY HAS BEEN ENTIRELY DISSIPATED, OR TRANSFORMED, THE BACK-WASH BEGINS, AND THE WATER FLOWS DOWN THE SLOPE IN A SMOOTH SHEET; THE TRANSPORTING POWER OF THE UP-RUSH ON THE UP GRADE MUST, FOR EQUILIBRIUM, BE EQUAL TO THE TRANSPORTING POWER OF THE BACK-WASH ON THE DOWN GRADE.

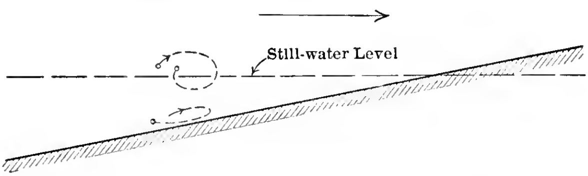

FIG. 4.—NEAR THE SHORE, AS A RESULT OF THE UNDERTOW, THE CLOSED ORBITS ARE REPLACED BY SPIRALS; NEAR THE SURFACE, THERE IS A PROGRESSIVE LANDWARD MOVEMENT, AND NEAR THE BOTTOM THERE IS A SEAWARD MOVEMENT.

Where the undertow exists, therefore, there must be a new condition of wave action, as shown by Fig. 4. Instead of moving in closed orbits, the particles of water move in spirals. Near the surface there is a progressive movement shoreward, and near the bottom there is a corresponding movement seaward. If, where there is a good surf running, a bather will raise his feet from the bottom and float on the surface, he will almost invariably drift toward the beach. If he is standing on the bottom, the nearly constant pressure of the undertow will frequently outweigh the occasional thrust of the wave and a considerable effort may be necessary to avoid being carried seaward. The undertow normally concentrates into streams of considerable velocity, and in such places the lower spiral of Fig. 4 is replaced by a current of varying velocity, but always flowing seaward.

The foregoing discussion of waves has been somewhat idealized. Waves ordinarily approach the shore from a diagonal direction, and the undertow leaves the beach by a diagonal on the opposite side of the normal. The undertow may concentrate into a stream nearly parallel to the beach and break out to sea at intervals. Such phenomena will be observed by any one making a study of a particular beach, and it will readily be understood that they are modifications of the idealized case.

The Origin of Beach Sand and Gravel.

The grinding away of rocky headlands and the accompanying reduction of ledge rock to gravel and sand is frequently referred to in print. Similarly, the wearing away of boulders as they are carried along by mountain torrents is a constantly recurring theme, attractive to the imagination. If, however, the prosaic engineer will pause for a moment to consider, it will be apparent that these are relatively unimportant sources from which beach sand is derived.

The constant agitation of a gravel beach must inevitably wear away the stones and gradually reduce their size. The rounded form of the pebbles is due to this wearing process. Each pebble is constantly reduced in diameter by the conversion of its outer skin into dust, but, by the time any given quantity of gravel can, by the attrition process, be reduced to grains of sand, there will remain only a small percentage of the original volume.

The principal source of sand in America is the verdure-covered mountain, hill, and valley. Wherever rain falls and vegetation grows the primary rocks are undergoing a process of disintegration. Certain components are carried away in solution, other constituents are transformed into clay, and the quartz crystals remain nearly unchanged. Let some of this decomposed rock, which is called soil, fall into a stream of running water, and the various sizes are quickly sorted out. The clay may be carried to deep water in the ocean without a halt, the finest sand may travel hundreds of miles before it is temporarily deposited, the coarser sand may be deposited within a few miles, and some fragments of rock may be rolled only a few feet during each freshet, and may, in traveling a few miles, be converted into typical rounded pebbles.

The nature of the sand found in most rivers and on most beaches is proof of its origin. It is the friable but insoluble quartz which has survived, and the grains are much more angular in form than pebbles formed by the attrition process. In the immediate vicinity of rocky cliffs, exceptions may be noted, and the writer has seen large areas covered with volcanic sand, but the beaches to which this paper particularly refers are no exceptions to the general rule.

Typical Beach Forms.

If all except wave action could be eliminated, the normal form of beach would be a series of berms. Several such berms are sometimes found in the case of gravel beaches. In the case of sand beaches, two berms are often noticeable.

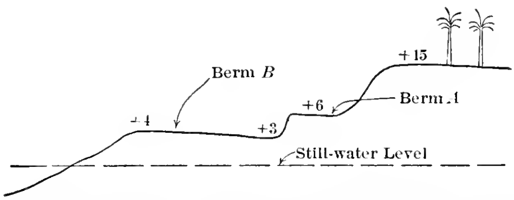

Fig. 5.—Beach at San Juan, Porto Rico, September 19th, 1915. The Cocoanut Grove Stands on Semi-Permanent Sand Dunes; Berm *A* Represents the Remains of a Much Wider Berm Built up During the Preceding Winter and Eroded Back to the Scarp During the Summer; Berm *B* was Formed During a Storm, about September 15th, 1915.

Fig. 5 shows a beach of the general character at San Juan, Porto Rico, as noted on September 19th, 1915. This beach builds up every winter during the stormy season. During the summer or quiet season, it cuts away, the limit of the cutting being indicated by the location of the cocoanut grove. Berm *A*, at Elevation + 6, was formed during the winter of 1914-15. By September, 1915, the beach had cut away as far as the scarp which, on September 19th, marked the limit of that berm. During a three-day storm about the middle of September, a new berm, *B*, was built up in front of Berm *A*, and at a lower level. The high bank on which the cocoanut grove stands represents a relatively permanent formation; the lower berms are temporary in character.

On September 26th, at a point about ¼ mile west of that represented by Fig. 5, erosion was under way, and the berm was eroded by the undermining action of waves of less height than those by which it was built. The older and higher berm was formed at the foot of the dunes, which represent a relatively permanent formation. Almost identical conditions existed at Long Beach, Long Island, on July 25th, 1915, and at Mattituck, Long Island, where the material was gravel, three berms were formed, but information as to the form of the beach below the low-water line at Mattituck was not as complete as could be desired. In general, there is some depth at which the beach quite suddenly assumes a much flatter slope than it has at and above the level of mean tide. Around New York City, with a mean tidal range of about 4.5 ft., this change appears to come at about the level of mean low water. At San Juan, Porto Rico, where the tidal range is about 1.1 ft., the change of slope is very sharp, and occurs in water from 2 to 3 ft. deep. A beach noted by the writer on the Island of St. Thomas was similar to that at San Juan.

Constructive and Destructive Power of Waves.

Just before the plunge, a wave, by virtue of the orbital velocities of its component parts, possesses a considerable store of energy. After the plunge, this energy is largely dissipated, due to the turbulent flow accompanying the up-rush. To preserve the equilibrium of the beach, the turbulent up-rush must have a sand-carrying capacity on the up-grade equal to that of the back-wash on the down-grade. Shoreward of the plunge-point, the constructive power of the up-rush is greater than the destructive power of the back-wash and undertow. The slope of the beach, taken in connection with the character of the beach material, is an indication of the extent of this difference. It would seem that, seaward of the plunge-point, the destructive agencies are more powerful than the constructive agencies. Referring to Fig. 4, it is seen that, near the bottom, the resultant movement is seaward. Unless the sand can be carried to the top of the wave, there is no force to carry it shoreward. The ultimate effect of wave action, therefore, is a constant transfer of sand from the beach to deep water in the ocean.

As already stated, there is, in the beaches near New York City, a change in slope near the line of mean low water. Above that line, the slope is the measure of the difference in transporting power, for the particular material under consideration, of the up-rush and the back-wash of the wave. In coarse sand at San Juan and at Seabright, N. J., this slope averages perhaps 1:12; at Long Beach, N. Y., with fine sand, the slope is perhaps 1:40. For any locality, this slope is nearly constant, regardless of the magnitude of the waves that have created it and regardless of whether it is the result of an addition to, or a denudation of, the beach. Seaward of the foot of this slope, the inclination of the bottom is much less.

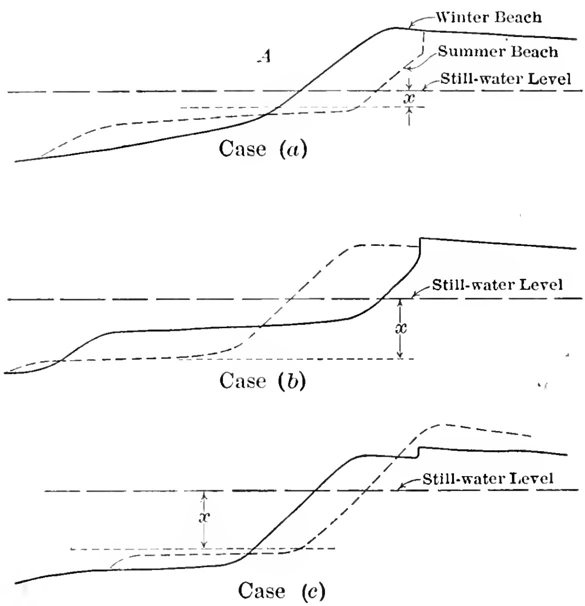

FIG. 6.—THE DEPTH OF WATER AT THE PLUNGE POINT IS INDICATED BY THE DIMENSION, x; THE FORM OF THE BEACH BEFORE IT IS ATTACKED BY WAVES PLUNGING AT THE DEPTH, x, IS SHOWN BY THE FULL LINE, AND THE NEW FORM ASSUMED IS SHOWN BY THE BROKEN LINE.

CASE (a) ILLUSTRATES THE EROSION OF A BEACH BY WAVES OF LESS MAGNITUDE THAN THOSE BY WHICH THE BEACH WAS BUILT UP.

CASE (b) ILLUSTRATES THE UPBUILDING OF A BERM BY HEAVY WAVES WHEN THE STILL-WATER LEVEL IS AT ITS NORMAL ELEVATION.

CASE (c) ILLUSTRATES THE RE-ADJUSTMENT OF THE BEACH FORMED IN CASE (b) WHEN ATTACKED BY WAVES OF THE SAME MAGNITUDE AS THOSE ASSUMED IN CASE (b), BUT STRIKING THE BEACH AT A TIME WHEN THE STILL-WATER LEVEL IS ABNORMALLY RAISED.

An explanation of the observed fact that berms, built up during stormy seasons, are eroded by the less violent wave action of the calmer seasons, and that berms attacked by storm waves may be either built up or eroded according to circumstances, may be obtained from Fig. 6, in which three typical cases are indicated.

Case (*a*) represents conditions such as exist when the winter berms are attacked by the summer waves. The plunge-point is at some depth, x, and this is the point of maximum disturbance. Shoreward of the plunge-point, the waves maintain a nearly fixed slope, as described in the last paragraph on page 634. Seaward of that point, the slope of the bottom is steeper than required for equilibrium. The result is a transfer of sand from the berm to the under-water section, and the summer beach indicated by the broken line is formed.

If now, Case (*b*), waves of greater magnitude attack the summer beach of Case (*a*), the plunge-point, in the average case, will be moved seaward to water of some depth, x. Shoreward of the plunge-point the slope of the beach is flatter than required for equilibrium, and a transfer of sand toward the beach commences. The ultimate result is a new berm such as shown by the broken line. It should also be noted that at the plunge-point there is also a transfer of sand seaward, and, as this sand is carried into deeper water than that where it lay in the summer beach, the probability of its eventual return to the beach has been diminished. In other words, though the berm has been rebuilt, a certain quantity of beach material has been wasted in the process.

In Case (*c*) it is assumed that the beach formed under Case (*b*) is, in turn, attacked by waves plunging in water of the same depth as in Case (*b*), but that the attendant circumstances are such that the still-water level has been raised. Under these conditions, the berm will be built to a higher level, but the sand used in this elevating process is taken from the face of the berm itself, and the width of the berm is correspondingly decreased.

Many other conditions might be assumed and discussed, but those chosen will show why the beaches around New York City, throughout the summer, present to the eye of a visitor a scarp indicative of erosion; they will show why, in many cases, if not in the majority, the berm at the beginning of the summer is wider than it was at the close of the preceding summer; they will also show why the maximum damage to beach structures usually occurs during an extraordinarily high tide.

The foregoing refinements might have been omitted, and the writer might have limited himself to a brief statement to the effect that, above a certain hydrographic contour, the waves exercise a powerful scouring effect on the bottom; that the sand composing the bottom is constantly agitated and can find no rest until it has reached deep water, or until it has been cast on the beach above high-water mark; that the greater the magnitude of the waves, the wider the zone of agitation, the higher the beach to which part of the material escapes, and the greater the depth to which other material is carried.

Along the south shore of Long Island, the waves, for the greater part of the year, beat on the shore from a direction slightly east of the normal to the shore line. This shore is protected from the northerly storms, and, if the northerly winds are eliminated, the remaining storms will come mainly from an easterly direction.

When a wave strikes the beach from a diagonal direction (Fig. 7), the up-rush carries sand along with it in a diagonal direction. The back-wash also follows a diagonal course, but on the opposite side of the normal. The undertow frequently concentrates into a stream nearly parallel to the shore line, flowing out to sea at irregular intervals.

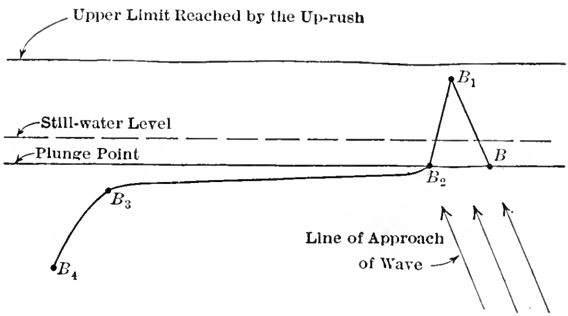

FIG. 7.—LITTORAL DRIFT IS MAINLY DUE TO UP-RUSH, BACK-WASH, AND UNDERTOW. A PARTICLE OF SAND AT B IS DISTURBED BY THE PLUNGE AND CARRIED BY THE UP-RUSH TO B_1, BY THE BACK-WASH TO B_2, AND BY THE UNDERTOW TO B_3 AND B_4.

With the assumed conditions, a particle of sand disturbed by the plunge at B might be carried up the beach as far as B_1. At B_1, the force of the up-rush having been nearly expended, the particle is dropped until the returning back-wash has acquired sufficient velocity to set it once more in motion. The back-wash carries it as far as B_2, where the undertow takes charge. The latter is assumed to be nearly parallel to the beach as far as B_3. At B_3 the undertow turns seaward, and the particle is carried into deep water.

The course followed by any individual grain of sand is an interrupted one, but, in the normal case, certain particles are at all times following each phase of the route shown in Fig. 7. The majority of the sand grains actually make many journeys up and down the slope, with a progressive movement to leeward, before they are finally taken to deep water by the undertow, or are carried to the semi-permanent uplands above the reach of the waves.

A study of the geology of Long Island indicates that during the glacial epoch enormous quantities of sand and gravel were deposited near the easterly end of the island, in a position where they were subject to wave attack. The prevailing direction of the waves has caused part of this material to be carried along the south shore for a distance of 100 miles, and has built up a nearly continuous beach along that shore.

The foregoing description of littoral drift applies to a continuous beach, and attributes the phenomenon of drift to wave action and undertow. It should be noted that any break in the continuity of the beach eliminates these forces. At such breaks, normally, there are tidal currents of considerable strength to be dealt with. Wave action keeps the bottom more or less agitated, and thereby assists the tidal currents in moving the sands.

It would seem that the question whether littorally drifting sand will be carried across an inlet to the leeward beach, to deep water outside, or into the harbor, is largely a matter of accident. In any event, inlets must result in a waste of beach-forming material, for there are strong tidal currents there which are capable of carrying the material far away from either the windward or the leeward beach.

Jetties and Groins.

As used by the writer, the term "jetty" will refer to structures reaching well out into deep water; the term "groin" will be applied to structures reaching only slightly beyond the low-water line. Wherever there is littoral drift, and jetties have been constructed, beaches have accumulated on the side from which the drift comes. Such is not the case with groins.

Referring to Fig. 7, it is noted that the littoral drift takes place largely below the still-water level. Above that level the sand movement is principally up and down the slope, with only a small component parallel to the shore line. A jetty cuts off the littoral drift, both above and below the still-water level. A groin has little effect on drift due to undertow, and, so far as the drift above still-water level is concerned, a groin is effective for a limited distance only.

One effect of groins deserves serious consideration. Consider a groin so high that no water will over-top it. Such a structure (Fig. 8) will inevitably concentrate both the up-rush and the back-wash of the wave. With a low groin a lesser concentration is effected. It has been the writer's observation that, in the normal case, the berm will be cut back, and a valley will be formed in the vicinity of a groin.

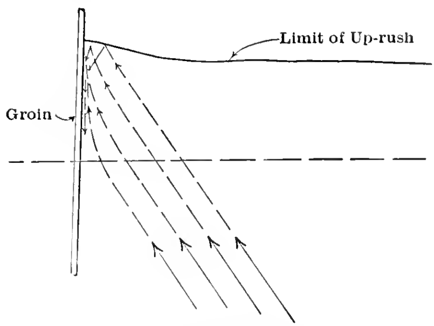

FIG. 8.—A GROIN INEVITABLY CONCENTRATES THE UP-RUSH AND THE BACK-WASH, AND DRIVES THE LITTORALLY DRIFTING SAND INTO DEEPER WATER THAN WOULD BE THE CASE ON AN UNOBSTRUCTED BEACH.

In the vicinity of an inlet, a training dike may be of great value in aiding the formation of a beach, even though it does not reach below the low-water line. At points where channels parallel to the beach (sometimes called swills) are formed, temporary dams across such channels may be of benefit, but, as the channels are transitory, permanent dams are unnecessary.

In order that littorally drifting material may pass a jetty, or a groin, it is necessary for it to travel into deeper water than would be the case on an unobstructed beach, and this deflection reduces the probability of its ever being returned to the beach. For these reasons jetties and groins must inevitably cause a wastage of beach material.

BULKHEADS.

When an engineer is required to build a bridge over a torrential river, he first searches for marks indicating the highest points reached by floods. Using the information thus obtained, he builds to resist the forces that must be encountered. Similarly, when erecting structures along a beach, he should take note of the signs showing what part of the beach is transitory and what part is fairly stable. The level of the cocoanut grove at San Juan, Porto Rico, and of the sand hills at Long Beach, Long Island, previously mentioned, represent formations that have remained in their present location for many years, and, in the ordinary run of events, may be expected to last for many years. Who builds in front of these stable formations should build strong.

Confronted by a wide berm, such as that at Long Beach, Long Island, the property owner is tempted to erect some form of bulkhead in advance of the line of dunes. The strength of the bulkhead is proportioned to resist the final attack of the waves after most of their force has been spent in crossing the berm. An unfortunate combination of seasons may entirely remove the protecting berm, as it has been removed in former years, and the bulkhead will then be subjected to forces for which it was not proportioned. The result is that the sea takes back its own.

The effect on the berm and foreshore of such substantial sea-walls as are represented by the rip-rap walls guarding the Edgemere Club, the Manhattan Beach Estates, and the neck of land connecting Sandy Hook with the mainland, and of such substanital bulkheads as guard the tracks of the Central Railroad of New Jersey, from Highland Beach to Seabright, should be considered. It is often stated that such structures cause an erosion of the beaches in front of them. The writer believes that this erosion is much less than is commonly thought. The destruction of the berm is usually brought about by the undermining of the other faces, as indicated in Fig. 6 (*a*), or by a rearrangement of the berm material, to obtain a higher berm of less width, as indicated in Fig. 6 (*c*). In the former case the quantity of material above mean low water is diminished; in the latter case it is increased. In both cases the width of berm is diminished.

Under certain conditions, the back-wash from a sea-wall may tend to undermine its toe by scouring out the bottom for a few feet in front of the wall, but the writer does not recall seeing a single instance of this kind along the many miles of bulkheads near New York City. To erode a berm like that at Long Beach, forces must work far to seaward and must carry the beach material to deep water, or must, by littoral drift, take it to another part of the beach. A sea-wall would have no material effect on such forces.

The wall in front of the Manhattan Beach property has stopped the erosion of that property, and there is no evidence that it has caused a deepening of the water in front of the wall. There is at the present time a large shoal between Rockaway Inlet and the Manhattan Beach Estates. That shoal is moving steadily westward, and there is no reason to believe that the existence of the wall would prevent the shoal some day from making a contact with the Manhattan Beach property and forming a beach in front of the wall, should other conditions be favorable to such a movement.

The records show that the beach in front of a considerable portion of the sea-wall at the south end of Sandy Hook builds out and cuts away. The sea-wall limits the extent of the erosion, but does not prevent the formation of a new beach when conditions are favorable.

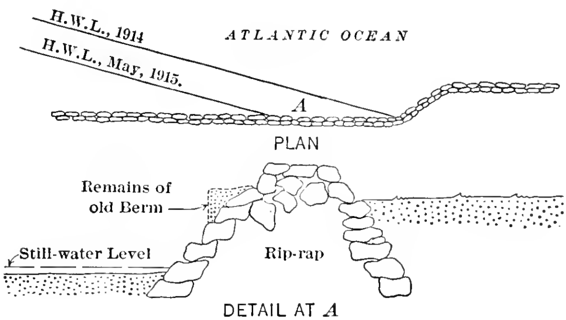

FIG. 9.—AT SANDY HOOK, N. J., THE REMAINS OF AN OLD BERM WERE SEEN WELL UP ON THE FACE OF THE SEA-WALL; BACK-WASH FROM THE SEA-WALL COULD NOT HAVE CAUSED THE EROSION UNDER WAY AT THE TIME.

In connection with this Sandy Hook wall, the writer on one occasion noted casually a condition that should have been carefully recorded and photographed. Its significance, however, was not realized until later. From memory, the conditions were about as shown in Fig. 9. The beach had eroded perhaps 200 ft. in less than a year. The inspection was made in May, 1915, during calm weather. Well up on the wall were the remains of the old berm, just as they had been left by the caving away of the outer part. The corners were sharp, and the caving may have taken place only a few hours before the inspection. It is highly improbable that the sand scarp would have stood as it was for more than 2 or 3 days, yet the beach had already receded many feet from this particular deposit. The essential facts are that the beach in question was being eroded at a rapid rate by waves that were too small even to splash the old berm. Certainly, back-wash from the wall was not the cause of the erosion, nor was the erosion due to the action of storm waves.

A sea-wall having strength commensurate with its exposure will effectively protect the property in its rear. The location of such a wall, however, should be a matter for serious consideration. If placed so as to include permanently a portion of the temporary berms, the sand thus confined must be deducted from the supply that might otherwise be counted on for the maintenance of the beaches to leeward. The right of a property owner to take permanent possession of beach material temporarily deposited in front of his property may well be questioned. A fair compromise would seem to be that the improvement of the semi-permanent formations be encouraged, and their protection by any means not interfering with the littoral drift be permitted, but that no structures having in view the fixation of the materials composing the temporary berms should be authorized unless the work is on such a scale as to constitute a public improvement, taking care of the beach as a whole.

If used to protect an isolated portion of the water-front, a bulkhead should be placed at about the line separating the temporary berms from the semi-permanent dunes, or in rear of that line. If the protection of the beach as a whole is undertaken, the bulkhead, sea-wall, or detached breakwater may be placed so as to include the temporary as well as the more permanent formations.

It should be understood that the construction of a detached breakwater or a sea-wall enclosing the berms will effectually stop the littoral drift along that frontage until a new beach has been formed outside of the sea-wall or breakwater. If there are beaches to the leeward the effect on them may be disastrous.

Detached breakwaters should afford protection to the beaches in front of which they have been placed. They should create along those beaches conditions similar to those existing in protected bays and harbors. So far as the protected beaches are concerned, rapid changes due to wave action will be done away with, and the beaches may be extended by dredging and filling if desirable.

Conclusion.

It would appear that along each mile of open beach there is a constant transfer of sand from the shore to deep water. When littoral drift is the source from which the supply necessary to maintain the beach is obtained, the quantity of material brought to the section must, in order to maintain the beach, be at least equal to the material carried into deep water plus that carried away by littoral drift.

Assuming a section of beach where the littoral drift is exactly sufficient to replace the wastage, no checking of the sand at any point will benefit the beach as a whole. The valuable part of water-front property is the part corresponding to the level of the cocoanut grove in Fig. 5, but the value of this portion is somewhat dependent on the existence of a sufficient berm at a lower level. Uplands may be protected by sea-walls and bulkheads, but bathing beaches must necessarily lie outside of such structures.

The writer knows of no means by which exposed sandy beaches for surf bathing may be preserved, except by feeding fresh beach material to them as rapidly as the old material is carried away. The rate of growth of Rockaway Point and Long Beach would indicate that many millions of cubic yards per year are required by the beaches of the south shore of Long Island to counterbalance the demands of the littoral drift. There are no data, so far as the writer is aware, by which the quantity of sand carried annually into deep water can be approximated. At all events, it is safe to say that, if the natural supply of beach maintenance material was to be cut off, any attempt to make up the deficiency by dredging or other artificial means would be a stupendous undertaking.

Along the New Jersey shore north of Asbury Park there remain to-day only a few isolated temporary berms. Along most of that shore the waves are eating into the semi-permanent formations or are battering against the bulkheads. It would seem that the only salvation for many sections of that beach lies in the construction of sea-walls of sufficient strength to combat the waves until such time as new berms are formed, if such time ever comes.

A study of the littoral drift on the south shore of Long Island and the disastrous results to certain beaches that have followed temporary stoppages of that drift would be well worth while. The stoppages in the past have been brought about by natural causes, but the works of Man will play an important part in the future, and we may well take warning while there is yet time and see to it that the interests of the millions who annually visit the beaches of the south shore are properly safeguarded.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

SURGES IN AN OPEN CANAL*

By R. D. Johnson, Esq.

Synopsis.

This paper points out a rational theory on which to base research into the question of the rise of water in a canal following an interruption of flow, due, for example, to a shut-down of a water-power plant; it calls attention to the analogy between this surge and the phenomenon known as the "hydraulic jump".

This interesting subject always comes up in connection with the problem of how high to build fore-bay walls to avoid overflow in case the motion of the water in a canal is suddenly arrested by a short circuit. Trouble from this source seems to be very infrequent, and yet a sound theory for the computation of the height of the surge wave has never come to the writer's attention. The reason that wash-overs have not been more common seems to be due to the fact that, for ordinary velocities, the surge is comparatively small, and a good fair guess usually proves a sufficient safeguard; nevertheless, it may be interesting to set forth what appears to be the beginning of a sound theory, applicable to such cases.

Neglecting friction, in a smooth, rectangular flume, the sudden dropping of a gate would seem to cause a backward rolling wave which consumes a part of the energy of the oncoming water in eddy losses, and accounts for the remainder in an increased depth behind the wave,

* This paper will not be presented at any meeting of the Society, but written communications on the subject are invited for subsequent publication in *Proceedings*, and with the paper in *Transactions*.

the water standing still and level between the wave and the gate. On this theory, an equation from which the depth of the water may be determined is expressible through recourse to the well-known law that force is equal to the rate of change of momentum; for, if the depth of the water in motion is d and that of the water at rest is D, the total free force acting (for unit weight of fluid and unit width of flume) is $\frac{D^2 - d^2}{2}$ and, in the time, t, during which Qt cubic feet of water passes, with a velocity, v, and also Qt cubic feet of water is projected backward over the top, so to speak, of the oncoming stream, the quantity of water brought to rest is Dt multiplied by the velocity of propagation of the wave, or,

$$Dtv_3 = Dt \times \frac{Q}{D - d},$$

the change of momentum is

$$\frac{DQtv}{g\,(D - d)},$$

and the rate of change of momentum is

$$\frac{DQv}{g\,(D - d)},$$

whence,

$$\frac{D^2 - d^2}{2} = \frac{D\,d\,v^2}{(D - d)\,g} \quad \text{..................... (1)}$$

from which D may easily be determined by trial.

It may be observed that as velocity is only relative, the height of the "jump" which takes place in this case should agree exactly with the formula for the "hydraulic jump", if the proper corrections are made in the velocities relative to the earth, in such manner that the wave would "stand still" in the ordinary acceptation of the term. In other words, no error in theory is introduced if, while the above phenomenon is in progress, the whole flume is regarded as moving, bodily, with a velocity, relative to the earth, equal and opposite to that of the wave propagation; and such modifications ought to, and do, reveal the formula for the ordinary "hydraulic jump".

In this case, the absolute velocity of the water approaching the wave would be

$$v + \frac{Q}{D - d} = v_2$$

and the absolute velocity of the deeper water, at depth, D, would be

$$\frac{Q}{D - d} = v_1, \text{ and } v_2 - v_1 = v, \text{ as before.}$$

The new quantity, $Q' = D v_1 = \frac{Q D}{D - d}$.

The formula for the hydraulic jump is,

$$\frac{D^2 - d^2}{2} = \frac{Q'}{g}(v_2 - v_1)$$

and as D and d are unchanged, we may substitute for the foregoing values of v_2, v_1, and Q', their equivalents in terms of Q and v, as follows:

$$\frac{D^2 - d^2}{2} = \frac{Q D v}{g (D - d)} = \frac{D d v^2}{(D - d) g},$$

thus disclosing the identity of the two formulas and justifying, to some extent, the reasoning outlined in the premises.

To complete the analogy, it may come to mind that, as water cannot "jump" unless it has a velocity greater than $\sqrt{gd}$, it would be well to demonstrate that the sum of the velocities, v and v_3, is always greater than $\sqrt{gd}$.

Note, from Equation (1), that,

$$\frac{v^2}{g} = \frac{(D + d)(D - d)^2}{2 D d}$$

and we are to show that

$$v + v_3 \text{ or } \frac{v D}{D - d} > \sqrt{gd},$$

that is, that

$$\frac{v^2}{g} > \frac{d (D - d)^2}{D^2},$$

or, eliminating $\frac{v^2}{g}$, that

$$\frac{D + d}{2 d} > \frac{d}{D},$$

which is obvious so long as $D > d$.

The surge, S, above the level of the quiet water previous to its acceleration into the canal entrance is evidently equal to $D - d - \frac{v^2}{2 g}$, and it may be shown by calculus methods that the maximum possible value of S is equal to $0.714d$, which occurs for a critical velocity of $v = 7.448 \sqrt{d}$.

Modifications Involving Friction.—It now seems clear that Equation (1) represents the relation between the depths on each side of the backward rolling wave when friction is neglected. Without attempting to go further into the subject at this time, it may be stated, nevertheless, that the surge probably cannot exceed the value of S derived from this equation, when friction is taken into account. On the other hand, there would seem to be little danger of extravagance if the height of the canal and forebay walls was regulated by the foregoing considerations.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

THE PROPERTIES OF BALSA WOOD
(*Ochroma Lagopus*)

By R. C. Carpenter, M. Am. Soc. C. E.

To be Presented June 7th, 1916.

Synopsis.

Balsa wood grows extensively in the Central American and northern South American States as a second-growth tree. It is the lightest wood known, so far as any evidence attainable is concerned. This paper shows the microscopical structure and also gives various tests of its transverse and compressive strength. The material is composed of very thin-walled cells, which are barrel-shaped, interlace with each other, and are almost devoid of woody fiber. These cells are filled with air, making a natural structure well adapted to prevent the transmission of heat, because of the particles of air imprisoned in the material without interconnecting fibers. Various tests of the insulating properties for resisting the flow of heat are given.

Balsa wood has been used quite extensively in the past as a buoyancy product for life preservers and in connection with the fenders of life-boats and rafts. Its life is short, under ordinary conditions, unless treated with antiseptic or preservative material. There is promise that it will have a field of usefulness, in the lines referred

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

to, which must make it of considerable interest to the engineer who requires either insulating material or buoyancy products.

Very little information is available respecting the wood of the balsa tree, which has recently been applied to several practical uses, and, as it possesses properties which make it valuable for many engineering purposes, the writer has thought it of sufficient interest to warrant the publication of the information which he has obtained regarding it. His interest in the wood was excited as the result of investigations as to its properties undertaken more than a year ago, and recently also by a visit to the Isthmus of Panama, where it grows extensively. The wood is remarkable: first, as to its lightness; second, as to its microscopical structure; third, as to the absence of woody fiber; fourth, as to its elastic character, in the sense of recovery from transverse deformation; and fifth, for its insulation qualities for heat. It is the lightest wood commercially useful so far as the writer has been able to ascertain, and it has considerable structural strength, which makes it suitable for a fairly extensive use.

The Weight of Balsa Wood.

Balsa wood, when thoroughly dried, has a specific gravity of 0.11. For reference, Table 1* shows the relative weights of various woods. Until recently, Missouri cork wood, weighing 18.1 lb. per cu. ft., was supposed to be the lightest, but recent investigations indicate that balsa wood is much lighter, having a weight of 7.3 lb. per cu. ft. The ordinary commercial balsa wood is seldom perfectly dry, and because of the moisture content its weight, as appears from a number of investigations made by the writer, will usually be between 8 and 13 lb. per cu. ft. As will be seen from Table 1, however, it is much lighter than cork.

Cellular Structure of Balsa Wood.

The cellular structure of balsa wood, as exhibited under a microscope, differs from that of any other wood known to the writer. All engineers know that wood is made up of a series of interlacing cellular bodies of microscopic size which, when joined together, form fibers which extend both radially and longitudinally. These cellular fibers

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* From the *Bulletin* of the Missouri Botanical Garden, August, 1915.

are interlaced, and, by their form and arrangement, give the wood its strength and physical properties. In ordinary woods the thickness of the walls of the cells is generally a considerable proportion of the diameter. The cells which are parallel to the axis of the tree are made up principally of woody fiber; those which extend in a radial direction usually have a cellulose structure with little woody fiber, and are defined as "medullary rays," or pith cells, because of their position and composition. The microscopic structure of all the woods involves, in addition, the existence of ducts or vessels scattered through the wood in a longitudinal direction; these serve as a circulatory system for the transmission of liquids and gases during the growth of the tree.

TABLE 1.—Weights of Woods.

Common name.	Scientific name.	Weight, in pounds per cubic foot.
Balsa	*Ochroma lagopus*	7.3
Cork	(Bark from cork oak, *Quercus suber*)	13.7
Missouri corkwood	*Leitneria floridana*	18.1
White pine	*Pinus strobus*	23.7
Catalpa	*Catalpa speciosa*	26.2
Cypress	*Taxodium distichum*	28.0
Douglas fir	*Pseudotsuga mucronata*	32.4
Sycamore	*Platanus occidentalis*	35.5
Red oak	*Quercus rubra*	40.5
Maple	*Acer saccharum*	43.0
Long-leaf pine	*Pinus palustris*	43.6
Mahogany	*Swietenia mahogoni*	45.0
Locust	*Robinia pseudo acacia*	45.5
White oak	*Quercus alba*	46.8
Hickory	*Carya alba*	54.2
Live oak	*Quercus virginiana*	60.5
Ironbark	*Eucalyptus leucoxylon*	70.5
Lignum-vitæ	*Guaiacum sanctum*	71.0
Ebony	*Diospyrus*	73.6
Black ironwood	*Krugiodendron ferreum*	81.0

Figs. 1 to 6 are reproductions from micro-photographs of balsa (*Ochroma lagopus*). Figs. 1 and 2 show cross-sections, Figs. 3 and 4 radial sections, and Figs. 5 and 6 tangential or longitudinal sections. In these illustrations, the ducts or vessels are denoted by (*a*), the medullary rays by (*b*), and the barrel-shaped cells which constitute the longitudinal fiber, by (*c*).

To W. W. Rowlee, Professor of Botany in Cornell University, who assisted in the investigations, the writer is indebted for the micro-photographs and also for the following botanical description:

"*Gross Characteristics.*—In general appearance, balsa wood resembles basswood. As shown by the accompanying micro-photographs, Figs. 1 to 6, its medullary or pith rays (*b*) are uniformly spaced, and are quite prominent in both the radial and cross-sections. In the radial sections, Figs. 3 and 4, they appear much as in maple or sycamore, as well as basswood, but lack the hardness and susceptibility to polish possessed by these woods. The ducts, pores, or vessels, shown at (*a*), are large and remote from each other, and occur singly, or in groups, in the strands between the pith rays (*b*).

"The lightness of the wood is one of its most striking features. This is due to the thinness of the walls of the elements. There is rather indistinct evidence of annual rings in the cross-section. In the specimens studied, the regular concentric rings, so characteristic of trees of temperate regions, do not show.

"*Minute Structure.*—The pith, or medullary ray cells (*b*) have normal position and form, but the cells are not elongated radially to so great an extent as is usually found in woods. The ducts (*a*) are large, with rather thin, pitted walls. Woody fibers of the ordinary sort seem to be absent in this wood, their place being taken by a cellulose tissue (*c*) very much like the thin-walled tissue of the pith and cortex of ordinary trees.

"The cells (*c*) making up this tissue are barrel-shaped, whereas woody fibers are taper-pointed and relatively much longer. The most remarkable thing about them, however, is their exceedingly thin, unlignified walls. A section of the tissue in question, examined under a microscope, would not be taken for wood, but rather thin-walled cells or 'parmchyma' from the pith or cortex of a stem. The only lignified part is the wall of the duct, and that is relatively weak.

"*Conclusions.*—

"1.—The gross structure of balsa wood is in appearance like basswood, poplar, or willow.

"2.—Its weight shows that it is fundamentally different from these.

"3.—Its minute anatomy is radically different from any wood known to the writer.

"4.—What correspond to the woody fibers, shown at (*c*), are not lignified. They are very thin-walled and soft.

"5.—The ducts or pores, shown at (*a*), are weakly lignified, and are pitted. They, however, constitute a very small proportion of the wood.

"6.—The pith rays, shown at (*b*), are also thin-walled and not lignified."

Microscopical Structure of White Pine (*Pinus Strobus*).—For the purpose of illustrating the interlacing fiber construction of ordinary woods, the writer presents micro-photographs of white pine, Figs. 7, 8, and 9, magnified about 100 diameters. Sections of the longitudinal cells are shown in Fig. 9 at *c c*; these have pointed ends, and are

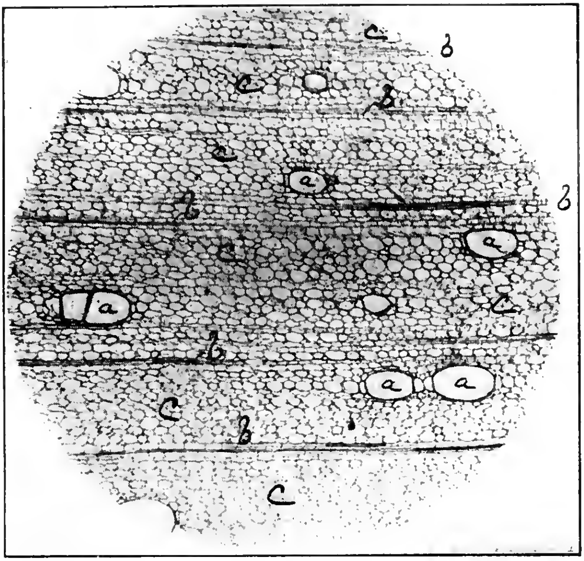

FIG. 1.—(*Ochroma lagopus*) CROSS-SECTION, BALSA, ABOUT 78 DIAMETERS, SHOWING (*a*) LARGE VESSELS, (*b*) MEDULLARY RAYS, (*c*) CROSS-SECTION OF LONGITUDINAL CELLS.

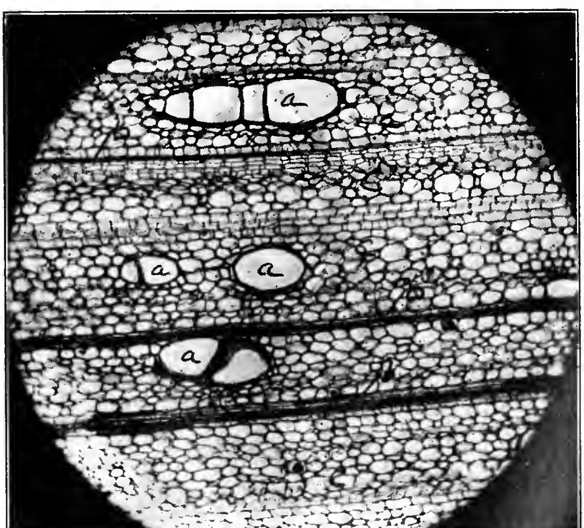

FIG. 2.—CROSS-SECTION, BALSA (*Ochroma lagopus*), SHOWING (*a*) LARGE VESSELS, (*b*) MEDULLARY RAYS, (*c*) CELLS CONSTITUTING LONGITUDINAL FIBERS.

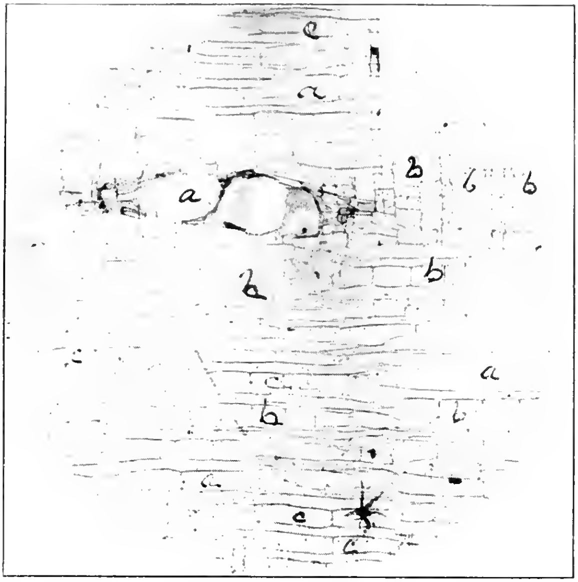

Fig. 3.—Radial Section, Balsa, About 70 Diameters, Showing (*a*) Large Vessels or Ducts, (*b*) Medullary Rays, (*c*) Longitudinal Cell Structure.

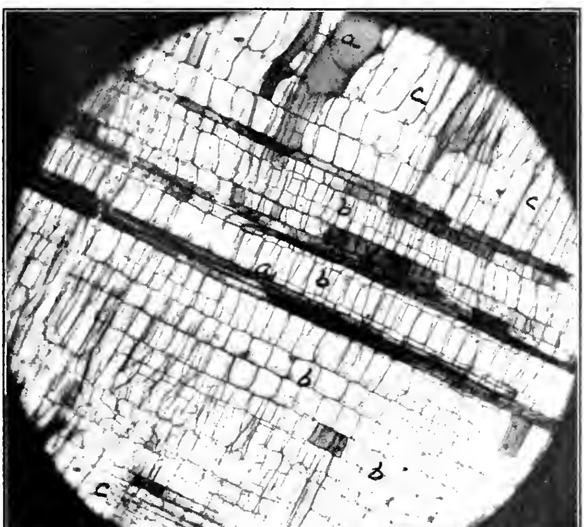

Fig. 4.—Radial Section, Balsa, About 130 Diameters, Showing (*a*) Vessels, (*b*) Medullary Rays, (*c*) Cells Constituting Longitudinal Fibers.

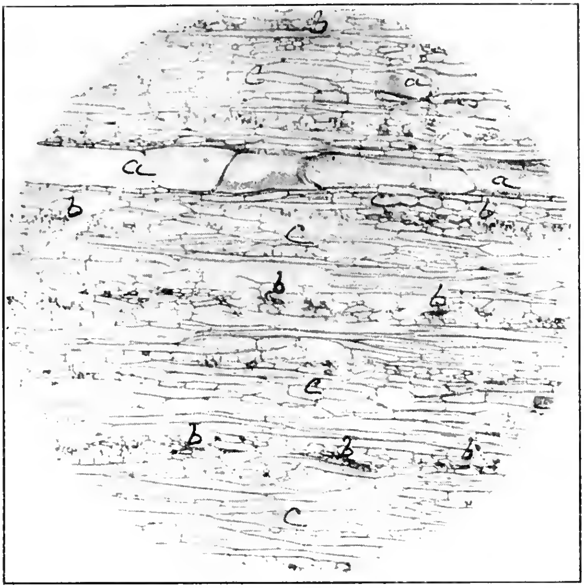

FIG. 5.—TANGENTIAL SECTION, BALSA, ABOUT 70 DIAMETERS, SHOWING (*a*) LARGE VESSELS OR DUCTS, (*b*) MEDULLARY RAYS IN CROSS-SECTION, (*c*) CELLS CONSTITUTING BARREL-SHAPED LONGITUDINAL FIBERS.

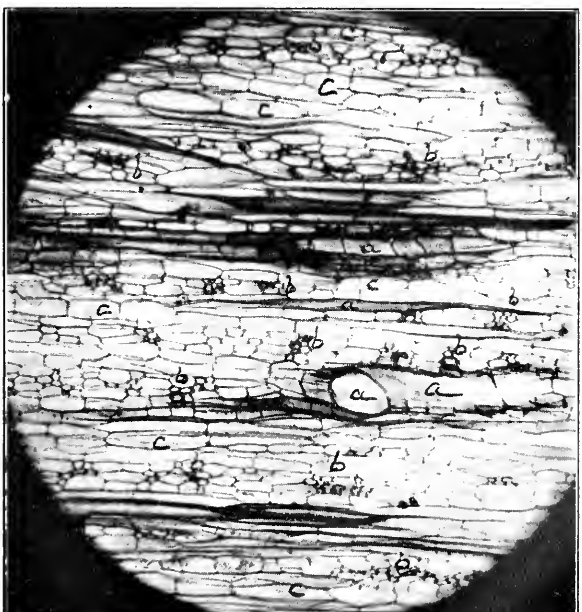

FIG. 6.—TANGENTIAL SECTION, BALSA, ABOUT 110 DIAMETERS, SHOWING (*a*) VESSELS, (*b*) MEDULLARY RAYS, (*c*) CELLS CONSTITUTING LONGITUDINAL FIBERS. NOTE BARREL FORM AND THIN WALL OF LONGITUDINAL CELLS.

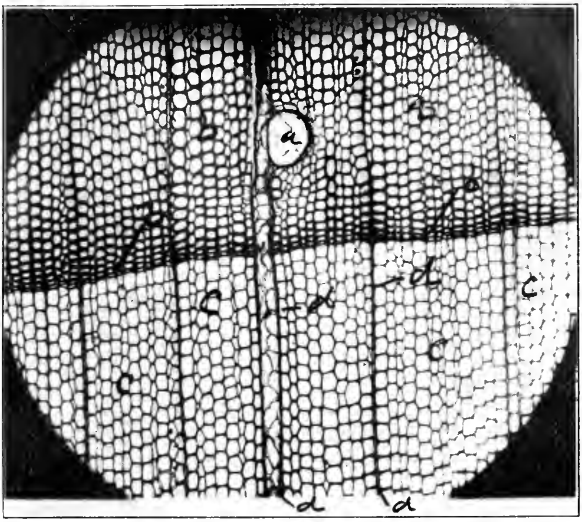

FIG. 7.—*Pinus Strobus* (WHITE PINE), ABOUT 100 DIAMETERS, CROSS-SECTION AT ANNUAL RING, *b* (OLD CELLS, UPPER PART WITH THICK WALLS, NEW CELLS BELOW WITH THIN WALLS). (*a*) VESSELS OR DUCTS, (*b*) LONGITUDINAL CELLS (OLD), (*c*) LONGITUDINAL CELLS (NEW), (*d*) MEDULLARY RAYS.

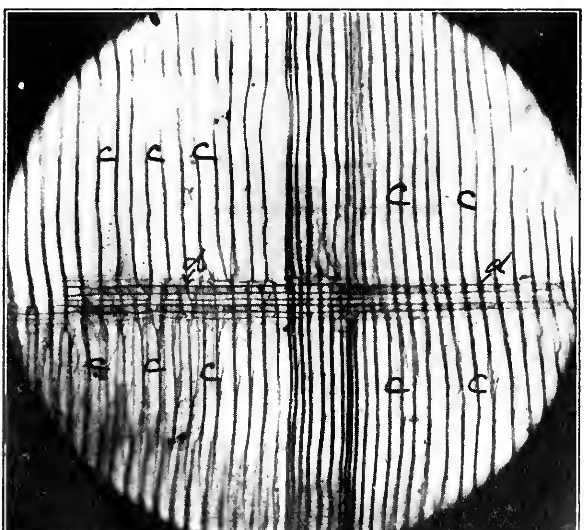

FIG. 8.—*Pinus Strobus* (WHITE PINE). ABOUT 100 DIAMETERS, RADIAL SECTION AT ANNUAL RING SHOWING (*d*) MEDULLARY RAYS, AND (*c*) PITTED TRACHEIDS OR LONGITUDINAL CELLS.

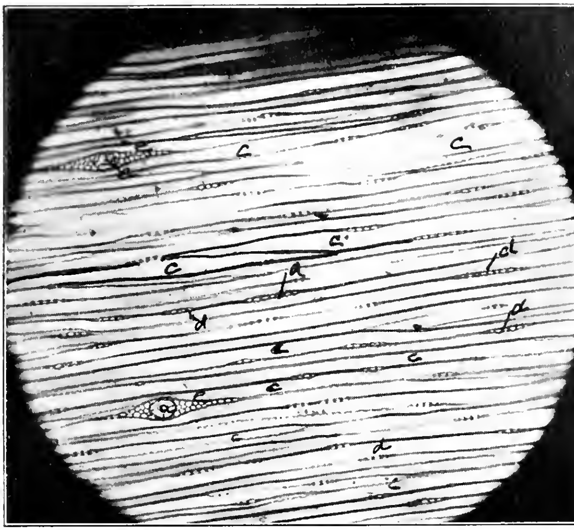

FIG. 9.—*Pinus Strobus* (WHITE PINE), ABOUT 100 DIAMETERS, LONGITUDINAL TANGENTIAL SECTION SHOWING (*d*) COMPOUND MEDULLARY RAYS, AND (*c*) PITTED TRACHEIDS OR LONGITUDINAL POINTED CELLS. THE LONGITUDINAL CELLS EXTEND BEYOND THE LIMITS OF THE FIGURE.

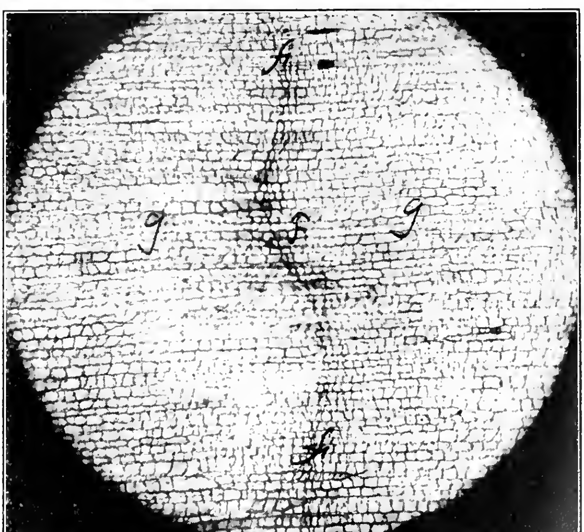

FIG. 10.—*Quercus Suber* (CORK OAK) BARK, ABOUT 100 DIAMETERS. CROSS-SECTION AT ANNUAL RING SHOWING (*f*) ANNUAL RING, (*g*) CROSS-SECTION OF CELLS.

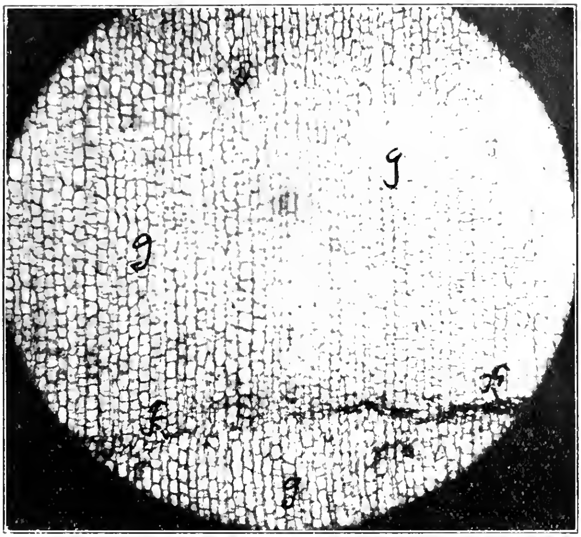

FIG. 11.—*Quercus suber* (CORK OAK) BARK, ABOUT 100 DIAMETERS, RADIAL SECTION AT ANNUAL RING SHOWING (*f*) ANNUAL RING, (*g*) RADIAL SECTION OF CELLS.

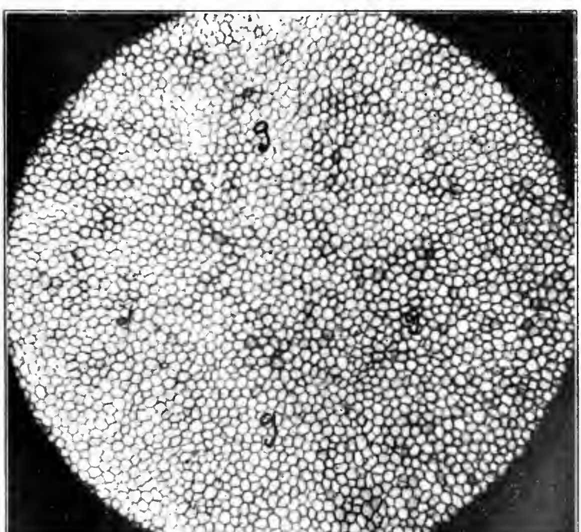

FIG. 12.—*Quercus suber* (CORK OAK) BARK, ABOUT 100 DIAMETERS, TANGENTIAL SECTION SHOWING (*g*) RADIAL CROSS-SECTION OF CELLS.

many times longer than the field of the microscope. They have walls of woody fiber which are much thinner in pine than in hard woods like oak, but are thicker than in balsa. The cells constituting the medullary rays are shown at *d* in Figs. 7, 8, and 9; they are devoid of woody fiber, and are much shorter than the longitudinal cells, *c*, but they are longer than any of the cells in balsa wood. Pine has a very different cellular structure from balsa, as shown by the micro-photographs. In pine the longitudinal cell walls are composed principally of woody fiber, and the medullary ray cells of cellulose. The cells of the older wood, near the annual ring, have very thick walls in pine, as appears from Fig. 7. Evidently, the cellular structure of white pine is characteristic of a heavier wood, of less insulating capacity than balsa, and in that respect predicates the difference in physical tests and in insulating properties.

The Microscopical Structure of Cork Bark.—As illustrating a wood product, already in extensive use for heat insulating purposes, which has a cellular structure without interlacing fibers, attention is called to the micro-photographs of bark from the cork oak, *Quercus suber,* Figs. 10, 11, and 12. These interesting illustrations show that cork bark is composed of a series of thin-walled cells of small dimensions, without the interlacing fiber characteristics, as in the woods considered. The balsa wood, with respect to this feature, may be considered as intermediate between pine and cork bark. The value of cork and balsa for insulating purposes is evidently due to the close union of numerous closed cells filled with air. The deficiency of cork in structural strength is due to the absence of interlacing fibers which characterize balsa and other woods. It represents the extreme of cellular structure. The cork bark contains, interspersed between the cellular structure, a resinous deposit which is utilized, by aid of pressure and heat, in forming cork board, which is usually put on the market in blocks, 2 or 3 in. thick and from 2 to 6 ft. long, convenient for use as a lining in cold-storage or other structures. Cork is soft and readily compressible, and represents extreme characteristics possessed by balsa wood in a less degree.

The Strength of Balsa Wood.

Table 2 shows tests made under the writer's direction at Sibley College, Ithaca, N. Y., and also as reported by Professor Walter S. Leland, formerly of the Massachusetts Institute of Technology.

TABLE 2.—TRANSVERSE TESTS OF BALSA WOOD.

No.	Dimensions, in inches.	Modulus of rupture.	Deflection, in inches.	Quality.	Where made.
A	1¾ by 2½ by 20	2 880	....	Medium	Cornell.
B	1¾ " 2½ " 20	3 290	....	Clear	"
C	1¾ " ½ " 20	....	0.847	Clear	"
D	1¾ " ½ " 20	....	1.123	Clear	"
1	5 by 5 by 96	3 500	2	Clear	M. I. T.
2	1¾ " 4½ " 96	3 600	1$\frac{5}{16}$	Poor	"
3	1¾ " 4½ " 96	2 900	1¼	Very poor	"
4	3$\frac{1}{16}$ " 4⅝ " 96	3 300	2$\frac{9}{32}$	Clear	"
5	1⅞ " 5½ " 96	3 207	....	Clear	"

Weight of Specimen *A*.................13.19 lb. per cu. ft.
" " " *B*.................10.05 " " " "
Average weight of Nos. 1–5.................13.2 " " " "

*Crushing and Compression Tests.**—Three specimens, each 1¾ by 2½ by 4 in., with a cross-section of 4.375 sq. in., gave an average of 2 488 lb. per sq. in. Another test of three specimens gave an average of 2 225 lb. per sq. in.

Three specimens, 1 by 1 by 3 in., crushed with loads of 2 210, 2 380, and 2 530 lb. per sq. in., respectively.

Two compression tests, of specimens 1 by 1 by 16 in., showed maximum loads of 1 860 and 1 980 lb., and net compression of 0.69 and 0.55 in., respectively.

One specimen, 5⅞ by 5⅞ by 23$\frac{25}{32}$ in. crushed under a load of 40 900 lb., equivalent to 2 500 lb. per sq. in.; and one slightly smaller gave substantially the same strength per unit of section as reported by Professor Leland in Table 2.

Professor Leland states:

"The crushing strength seems to be very satisfactory for such wood—about one-half the strength of white pine or spruce.

"These tests show the modulus of rupture to be approximately one-half that of good spruce, and their uniformity clearly shows that the material may be relied on both for direct compression and transverse loads.

"It is very elastic material, and when the load was almost at the breaking point, the load on three of the beams was removed and the beams resumed their original shape.

"It is exceedingly interesting to note that it is practically impossible to split the wood by driving nails through it."

Fig. 13 shows a balsa wood plank supported on horses and carrying two men, the plank being 5½ in. wide, 1¾ in. thick, and 10 ft. 8 in.

* Except where otherwise noted, these tests were made at Cornell University.

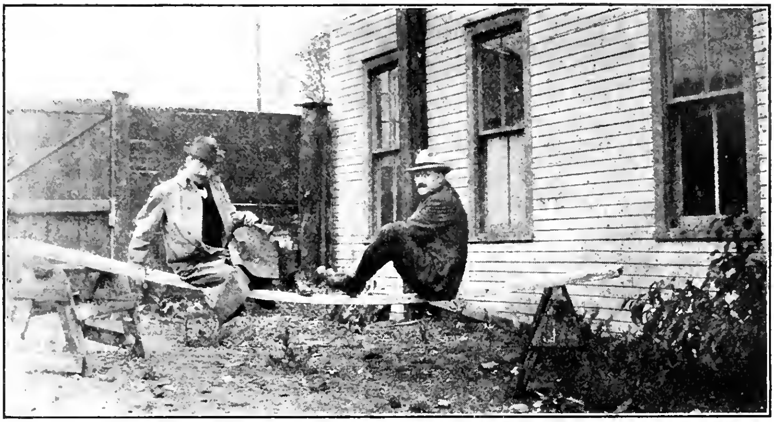

Fig. 13.—Demonstration of the Elastic Deformation of Balsa Wood.

Fig. 14.—Appearance of Young Balsa Trees, Costa Rica.

between supports. The weights carried were 187 and 200 lb., respectively. The maximum deflection at the center was about 10 in.

The Habitat.

In a recent trip to the Isthmus of Panama the writer found balsa trees growing commonly in all the cleared spaces which were not under cultivation in the Canal Zone. Most of these trees were of small diameter, and evidently quite young, and in every instance they were found in the newly started jungle which has recently been allowed to grow ever a goodly part of the Canal Zone since the canal has been completed. In some cases these trees were growing vigorously in the masses of material sliding into the canal. The tree is characterized by a large leaf, from 14 to 30 in. in greatest length, which has a form shown in Fig. 15, and by the peculiar seed pods which it bears when it reaches a larger size. Excellent evidence was obtained that the balsa tree grows very rapidly, and attains a diameter of from 12 to 14 in. at an age of 4 or 5 years. Rear-Admiral H. H. Rousseau, M. Am. Soc. C. E., now in charge of considerable construction work in the Canal Zone, told the writer that a balsa tree which was growing near his house at Culebra attained dimensions approximating 12 to 14 in. in diameter and from 40 to 60 ft. in height, in about 4 years. A considerable quantity of balsa of large size is to be found near the cleared plantations along the Chagres River, and in various other places near the Atlantic Coast and the banana plantations.

The result of an investigation of the forests of a number of tropical countries, by Mr. Herbert Paschke, undertaken for Capt. A. P. Lundin, indicates that balsa trees are found in considerable quantities in Honduras, Costa Rica, Colombia, and Jamaica, and there is abundant evidence that it grows vigorously in most of the tropical countries of South America. The report referred to indicates that the balsa or *ochroma* is entirely a second-growth wood, and is never found in the virgin forest, except as an isolated tree or two where clearing has occurred. The writer also learned, from his visit to the tropics, that forests composed of any one species do not exist in tropical countries, as they are found in the United States. Tropical trees always grow individually or by themselves, and very rarely in close proximity to other trees of the same species. This fact makes it necessary to spend considerable sums for transportation in gathering any tropical timber, as great distances through the jungle have to be traversed in order to obtain the timber of a single tree. The general characteristics of the growing balsa tree are shown clearly in Fig. 14, reproduced from a photograph taken in Costa Rica.

Mr. Paschke states that balsa wood is known by different names in various American tropical countries, as follows:

In British Honduras.............. "Moho"
In Guatemala .... "Lanillo" or "Moho"
In Spanish Honduras............. "Guano"
In Costa Rica.................... "Balsa"
In Bocas del Toro................ "Moho"

Balsa wood, because of its lightness, has been known for a long time as a desirable material for floats, for supporting other material, and for rafts. Professor Gifford states that in the West Indies the natives use it for poles* "somewhat as the Chinese use the bamboo for shoulder poles, for all uses where a light, rather strong pole is needed." So far as the writer could learn, balsa wood has no commercial value with people in the tropics who know about it, the general idea being that its lasting power is very slight, and that it warps and checks when exposed to the weather so as to be of little or no practical use.

Mr. W. F. Morgan, who recently made an investigation regarding the growth of balsa wood in Costa Rica, states that the natives are in the habit of cutting large balsa trees simply for the seed pods, which grow a woolly fiber suitable for pillows and mattresses. Fig. 16 shows a log of balsa wood, about 2 ft. in diameter, the tree having been cut down merely for the seed pods. Mr. Morgan also states that it has been the custom to use balsa wood in rafts of heavy timber for the purpose of securing buoyancy. At the end of a voyage, this wood is thrown away as having no commercial value.

It is thought that the first person to make any extended commercial use of balsa wood was Capt. A. P. Lundin, President of the Welin Marine Equipment Company, and formerly connected with the Pacific Mail Steamship Company. From his travels in tropical countries, Capt. Lundin knew of the extreme lightness of this wood, and its value as a buoyancy material in life preservers and lifeboats was sug-

* von Schrenk.

FIG. 15.—THE LEAF OF THE BALSA TREE.

FIG. 16.—BALSA WOOD LOG. TREES CUT FOR SEED PODS.

gested by its properties. When he undertook to apply the wood practically, however, he found that it was of little value because it absorbed moisture in great quantities, and also because it soon rotted, and also warped and checked when worked. He then undertook the discovery of some means of treating the wood which would render it water-proof and also prevent it from changing its shape. After testing nearly every method that had been suggested, Col. Marr's method of treating woods, which had been recently patented, was finally successful. In this method the wood is treated in a bath, of which the principal ingredient is paraffin, by a process which coats the interior cells without entirely clogging up the porous system. The paraffin remains as a coating or varnish over the interior cell walls, preventing the absorption of moisture and the ill effects as to change of volume and decay which would otherwise take place; it also prevents the bad effects of dry rot, which follows the use of any surface treatment for preserving wood of the balsa type.

The Marr process tends to drive out all water and make the wood water-proof; it improves the quality of being readily worked with tools, without material increase of weight. The treated balsa wood has been used extensively by the Welin Marine Equipment Company in the manufacture of life preservers, fenders for lifeboats, and for structures requiring insulation from heat, as in the refrigerating compartments of vessels, and in ice boxes.

Transmission of Heat.

Specific Conductivity.—The Bureau of Standards, Washington, D. C., has determined the "specific conductivity", *e*, of balsa wood with the following results, expressed in British thermal units per hour, per square foot per inch of thickness, per degree Fahrenheit of difference in temperature between the surfaces.

e for untreated balsa wood.	*e* for treated balsa wood.
0.394 B. t. u.	0.422 B. t. u.
0.352 "	0.350 "
0.403 "	0.424 "
	0.383 "

The lowest results obtained with both the treated and the untreated wood indicate a "specific conductivity" of 0.350. The higher results in other cases are to be attributed to imperfect specimens, or to imperfect contact of the heat measuring devices. The Bureau of Standards uses electrical methods in measuring the heat supply and the temperature of the surfaces of the material, in order to eliminate all surface losses. The "specific conductivity" corresponds to e in the equation.

$$H = \frac{e}{x} (\theta - \theta'),$$

where x = the thickness, θ = the temperature of the entering surface, θ' = the temperature of the discharge surface, and H = the heat transmitted.

Heat Transmitted by Melting Ice.—Table 3 gives the results of the writer's investigation of heat transmission by determining the quantity of ice which melted in boxes made of balsa wood and other materials under known differences of temperature measured inside and outside. The results were reduced to British thermal units transmitted per square foot of mean surface between the outside and inside surfaces of each box, per degree of difference of temperature of the air inside and outside, per hour of time, which correspond to the "coefficient" of heat transmission, k, in the equation,

$$H = k\ (T - T'),$$

in which T = the temperature of the air on the entering side, and T' = the temperature of the air on the discharge side, the other symbols being as before stated. The coefficient, k, differs from the "specific conductivity", e, of the previous equation as it is dependent on the surface as well as the conduction capacity for heat transmission.

Relation Between "Specific Conductivity" and "Coefficient of Heat Transmission."—It is evident that the quantity of heat transmitted through any body is equal to that passing in succession each heat-resisting part. For example, if heat passes through a simple homogeneous body from a higher to a lower temperature, and from the air on one side to that on the other side, it must overcome: (1) the resistance of the entering surface, (2) the resistance of the material composing the body, and (3) the resistance of the surface from which it emerges. The surface resistances, (1) and (3), are overcome by radiation and convection, the interior resistance, (2), by conduction. The surface capacity for transmitting heat may be considered as equal to the convection capacity plus the radiation capacity. The coefficients of radiation for most materials are known accurately, and may be calculated for different temperature conditions by the application of Stefan's or DuLong and Pettit's Law. The coefficients of convection are not known so accurately, but the values as stated by German engineers appear to give reliable results.

TABLE 3.—HEAT TRANSMISSION EXPERIMENTS IN SIBLEY COLLEGE. TESTS MADE BY MELTING ICE.

No. of test.	Thickness of wood, in inches.	British Thermal Units per Square Foot per Degree of Difference of Temperature of Air.		Kind of material.
		Per hour k.	Per 24 hours k'.	
1	2	0.121	2.90	Balsa wood, treated.
2	2	0.120	2.89	Balsa wood, treated.
3	2	0.122	2.93	Balsa wood, untreated.
4	2	0.192	4.61	White pine.
5	2	0.102	2.45	Nonpareil cork, extra.
6	2	0.122	2.93	Balsa, single boards, treated.
7	2	0.121	2.90	Balsa, double boards, at right angles.
8	2	0.1194	2.67	Armstrong, XX-cork blocks.
9	3	0.191	2.18	Balsa wood, treated.
10	2	0.1194	2.87	Balsa wood, treated.
11	1	0.199	4.78	Balsa wood, treated.
....	1/16	0 660	15.82	Bare zinc. 1/16 in. thick.

k = coefficient of heat transmission per degree Fahrenheit of difference of temperature of air near the sides, per square foot, per inch of thickness, per hour ;
$k' = 24\ k$.

The Bureau of Standards has given the name "specific conductivity" to the quantity of heat conducted, in British thermal units per square foot per hour, per inch of thickness, per degree of difference of temperature of the walls; and this term is used in this paper. This method does not consider surface losses, which vary with conditions. Engineering computations of heat transfer must usually be made by considering the temperatures of the air on the two sides, and require a knowledge of a coefficient of heat transfer per unit of area, per inch in thickness, per degree of difference of temperature of the air on each side, represented herein by k.

The following equations give the relation between "specific conduction", e, and "coefficient of heat transmission", k. They are rational.

and are recognized by French and German engineers as accurate. In the equations which follow,

H = heat transmitted per unit of surface per unit of time;

e = "specific conductivity", or heat transmitted per degree of difference of temperature of the sides of the material, per unit of time, per inch of thickness;

x = thickness;

a_1 = coefficient of surface flow entering the body;

a_0 = " " " " leaving the body;

k = coefficient of total heat transmission per degree of difference of air temperature, per inch of thickness;

$T - T'$ = difference of temperature of air on two sides;

$\theta - \theta'$ = " " " of material on two sides;

$t = T - \theta$ = drop of temperature entering the material;

$t' = \theta' - T'$ = drop of temperature leaving the material.

As the flow of heat is continuous, we have the following expressions, all equal to each other, as representing the flow through a single wall of homogeneous material without air space, per unit of surface, per unit of time:

Flow by conduction through interior.. $H = \frac{e}{x} (\theta - \theta')$....(1)

Surface flow entering................ $H = a_1 (T - \theta)$....(2)

Surface flow leaving................. $H = a_0 (\theta' - T')$...(3)

Total heat transmission.............. $H = k (T - T')$...(4)

From these we can readily deduce

$$\frac{1}{k} = \frac{1}{a_1} + \frac{1}{a_0} + \frac{x}{e} \quad \text{.....................} (5)$$

from which the relations between k and e can be computed, provided the values of a_1 and a_0 are known.

The foregoing equations apply to a single thickness without air space; but it is easy to calculate, by the same process of reasoning, the heat transmission through walls made up of various materials with or without air spaces. In the case of a wall made up of two different materials with an air space between, we should find by calculation

$$\frac{1}{k} = \frac{1}{a_1} + \frac{x}{e} + \frac{1}{a_0} + \frac{1}{a_1'} + \frac{x}{e'} + \frac{1}{a_0'} \ldots\ldots\ldots\ldots (6)$$

The temperature of the surface can be readily deduced by transposition in the equations given, thus, from Equation (2),

$$\theta = T - \frac{H}{a_1} \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

The surface transmission coefficients have been worked out carefully for numerous cases by Rietschel and other German engineers. These are given by Kinealy,* in English units, as follows:

$$a = c + d + \frac{(40c + 30d)\ t}{1\,000} = c\ (1 + 0.004\ t) + d\ (1 + 0.003\ t)$$

$c = 0.82$ for still air;
$c = 1.03$ for air with moderate velocity;
$c = 1.23$ for air with high velocity.

Values of d.†

Brickwork	0.74	Iron, rusted	0.69
Mortar	0.74	Cast iron, new	0.65
Plaster of Paris	0.74	Sheet iron, polished	0.009
Stone masonry	0.74	Brass, polished	0.053
Wood	0.74	Copper "	0.033
Paper	0.78	Tin "	0.045
Glass, dry	0.60	Zinc "	0.049
Glass, wet surface	1.09	Zinc, dull	0.10

For thick walls and poor conductors, t is so small that it can be neglected. Rietschel gives values of t, for windows, as 36; for brickwork 5 in. thick, as 14; for brickwork 30 in. thick, as 5, for wooden doors, as 2.

Comparison of "Specific Conductivity", e, with "Coefficient of Heat Transmission", k.—The following computation is based on an assumed value of the "specific conductivity" ($e = 0.35$), as determined by the

* "Formulas and Tables for Heating", New York, David Williams Company.

† This table is the same as the Péclét table (see E. Péclét, "Traite de la Chaleur") for coefficients of radiation reduced to English units.

Bureau of Standards, a_0 and a_1 as computed from the preceding equations, and coefficients, which are as follows:

First, For a Single Wall Without Air Space.—

$$a_0 = a_1 = 0.82 + 0.74 + 0.01 = 1.57$$

These values substituted in the general equation, give

$$\frac{1}{k} = \frac{1}{1.57} + \frac{1}{1.57} + \frac{x}{e}.$$

This, solved for $e = 0.35$ and for values of $x = 1$, 2, and 3, gives the following results:

"Specific conductivity."	Thickness, in inches.	"Coefficient of heat transmission."
$e = 0.35$	$x = 1$	$k = 0.242$
$e = 0.35$	$x = 2$	$k = 0.143$
$e = 0.35$	$x = 3$	$k = 0.1015$

Second, Single Balsa Wall, Ice in Zinc Box; Representing Test Results.—A box of balsa in still air, having thicknesses of 1, 2, and 3 in., respectively; melting ice confined in a dull zinc box, $\frac{1}{64}$ in. thick, the inside of which is in contact with the ice but separated from the balsa wood by an air space. These conditions correspond to those of the ice-melting test of which the results have been stated, and to which Equation (6) applies. For these conditions, $a_0 = 0$, and $\frac{x'}{e'}$ is so small that it is negligible.

Substituting numerical values, we have

$$a_1 = c + d = 0.82 + 0.10 + 0.92$$

$$\frac{1}{k} = \frac{1}{1.57} + \frac{1}{1.57} + \frac{x}{0.35} + \frac{1}{0.92}.$$

This, solved for different values, gives the following results:

"Specific conductivity."	Thickness in inches.	"Coefficient of heat transmission."
$e = 0.35$	$x = 1$	$k = 0.192$
$e = 0.35$	$x = 2$	$k = 0.124$
$e = 0.35$	$x = 3$	$k = 0.091$

Table 4 gives a comparison of the determinations of k by computation (assuming $e = 0.35$) and test.

TABLE 4.—RESULTS WITH BALSA WOOD BOX.

"Coefficient of Heat Transmission," k.
"Specific Conduction" e.

Thickness of box, in inches.	By computation, assuming $e = 0.35$ (for 1 hour).	BY TEST, MELTING ICE, IN A ZINC BOX, INSIDE BALSA.	
		k for 1 hour.	k' for 24 hours.
1	0.192	0.199	4.78
2	0.124	0.121	2.90
3	0.091	0.091	2.18

Engineers using insulating material for cold storage generally express the heat transmission coefficient on the basis of the heat, in British thermal units transmitted per degree Fahrenheit of difference in temperature of the air on the two sides, through material 1 in. in thickness, and for a period of 24 hours, which corresponds to k' in Table 4. The coefficient for 1-in. material is generally assumed as equal to twice the result obtained in a test of 2-in. material. In practice, only materials 2 and 3 in. in thickness are used, so that the coefficient obtained on such a basis, though not scientific, gives results which are fairly close. On such a basis, the "coefficient of heat transmitted" through balsa wood, per inch of thickness, computed from the Bureau of Standards tests, is 5.98; and, as determined by ice-melting experiments in Sibley College, is 5.80.

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CONTROL OF THE COLORADO RIVER AS RELATED TO THE PROTECTION OF IMPERIAL VALLEY

By J. C. Allison, Assoc. M. Am. Soc. C. E.

To be Presented September 6th, 1916.

Synopsis.

The general problems involved in the control of the Colorado River and the conservation of its waters for irrigation have already been treated exhaustively in papers and discussions before the Society, and it is not the intent of the writer to reopen the subject for purposes of debate. In this paper the direct relation of river control to the maintenance and ultimate perfection of levee systems protecting Imperial Valley, California, is the fundamental topic, as it has been the phase of the subject with which the writer necessarily has been most concerned.

In a broad sense, the problem of excluding the Colorado's overflow from the Valley has been solved. The maintenance of existing lines of defense, and the establishment of exterior auxiliary or supporting lines, may be considered as matters of detail. Final and complete protection, making possible the reclamation and beneficial use of all the arable lands of the delta, is to be secured, in the opinion which the writer holds in common with other engineers acquainted with the

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Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings,* and, when finally closed, the papers, with discussion in full, will be published in *Transactions.*

situation, most satisfactorily by forcing the river back into the bed that it abandoned in 1910, and keeping it there with impregnable retaining works.

Methods of accomplishing that feat have been discussed, and estimates of cost have been made by several engineers, but methods and estimates have been based on emergency closures of breaks of the Colorado which, the writer believes, do not necessarily govern the case. Immediate protection being afforded by lines of defense which may be maintained with no difficulty and at small cost, the restoration of the river to its old channel is no longer an urgent need, and does not call for emergency methods. A favorable time may be chosen for the work, and methods less expensive than those heretofore considered may be applied.

It is safe to assume that engineers generally know the situation of Imperial Valley in relation to the Colorado, and only a brief statement of the problems presented to operators of the irrigation system will be necessary. The slope of the Valley from sea level at the Mexican boundary line is northward to the Salton Sea, 280 ft. below sea level. About 25 miles south of the line is the highest land in the delta, the elevation of which, before the change in the river's course, was 34 ft. above sea level at the westward end of the delta cone. The normal elevation of the river bed at the canal intake is about 100 ft. above sea level.

In flood season, which reaches the maximum in June, the river overflows the delta south of the crest of the delta cone, and fills a shallow sink at the west end known as Volcano Lake. The most rapid fall is southward, and the flood-waters find their way to the Gulf of California through Hardy's Colorado, which drains Volcano Lake; but the cone is so flat that some of the flood-waters normally spill from the lake northward into what was a shallow drainage channel known as the New River.

In 1905 the river broke through its bank north of the delta cone, or "Paredones" crest, and flooded the north slope of the delta. In draining off the inundated land to the Salton Sink, the water cut deep gorges in New River and in another drainage channel on the east side of the Valley, known as the Alamo. In the event of another incursion of the river, the gorges would carry the water, and there would be no inundation of farm lands on the American side. If permitted to flow for any great length of time, the flood in the New River gorge would cut back the grade, and in time the recession would reach the old channel and lower the bed below the level of the intake, so that no water could be diverted into the main canal. Therefore the menace to Imperial Valley of an unchecked break would be drought, not inundation.

The problem presented by the change of course of the river through the delta in 1910, following the drainage channel known as Bee River to Volcano Lake, and thence through the Hardy, was the prevention of a northward flow into New River. That problem was solved by building the Volcano Lake levee, and by extending the Paredones levee of the California Development Company, parallel with the Bee River.

A deposit of silt raises the bed of Valcano Lake and consequently the surface elevation of the overflow water, and that has been met by increasing the height and cross-section of the levee. A small break in the levee in 1914 allowed some of the overflow water to go northward, but it was diverted easily from the head of New River gorge and turned into New River at a point where it did not produce any dangerous recession of grade.

Interior Lines of Defense.

North of the levee paralleling Bee River, which is now the main Colorado, interior lines of defense exist, and may be strengthened and extended very readily. The Inter-California Railroad grade serves as a barrier, and it may be connected with the Volcano levee. The function of interior lines would be to intercept and divert to the west a shallow body of overflow water having no defined channel and no eroding velocities. Numerous canal banks also serve as auxiliaries to check velocities and turn the water westward, where it may be taken care of readily.

The effect of one of these canal banks on the overflow of 1914 suggests a third line of defense and a method of diverting any water that might pass the Paredones and Volcano levees. This canal is the New Alamo Mocho, constructed by a rancher in Mexico to irrigate a large tract lying on both sides of New River channel. The water that came through the levee break, about 6 000 sec-ft., spread over the ground in a wide, shallow sheet, and was held by the canal bank, along which it flowed slowly to the west.

Assuming a breach in the Volcano Lake levee to be closed promptly, the inflow northward would be cut off before the slowly spreading sheet of water reached the west end of the proposed Alamo Mocho Canal bank, and it might not be necessary to let the water into New River at all. The overflow could be impounded and used as a reservoir for the West Side Main until drained off.

Each year prior to the break of 1905-06, which eroded the bed of New River, the overflow water from the Colorado entered on the northern slope of the divide. Each year this flow to the north subsided of its own accord, before the flow of the water to the south. The interior line of defense cuts off the water from entering New River gorge and so reinstates former conditions.

As an interior line of protection in emergency arising through possible failure of the primary lines, this proposed extension of the Alamo Mocho bank as a diverting levee seems entirely feasible and comparatively inexpensive to construct and maintain. It is important that the run-off channels leading southward from Volcano Lake be kept open and free from obstruction. Bee River has now cut a defined channel for itself through the silted Volcano Lake, and may be expected to keep to that approximate course for a long time.

Primary Line of Defense.

Only through negligence and failure to maintain the old California Development Company levee from Hanlon Heading south could the river again get into the region that was flooded in 1905-06, and be a menace to the Alamo Canal and delivery structures. The existing levee, properly maintained and protected from destruction by erosion of the banks of the river, is sufficient protection to the canal system as far as it extends. In 1914 a breach at the point where the levee bends to the southward resulted from negligence. Erosion of the river bank threatened the levee two years before the breach occurred.

The danger could have been averted by inexpensive means, but responsibility for the maintenance of the levee was a matter of controversy, and nothing was done until the bank and a point of the levee had been cut away by the river. Much money was wasted in an attempt to close the breach by the trestle and rock fill method on the line of the original location. The attempt was a complete failure, and the simple expedient of building a levee around the break was

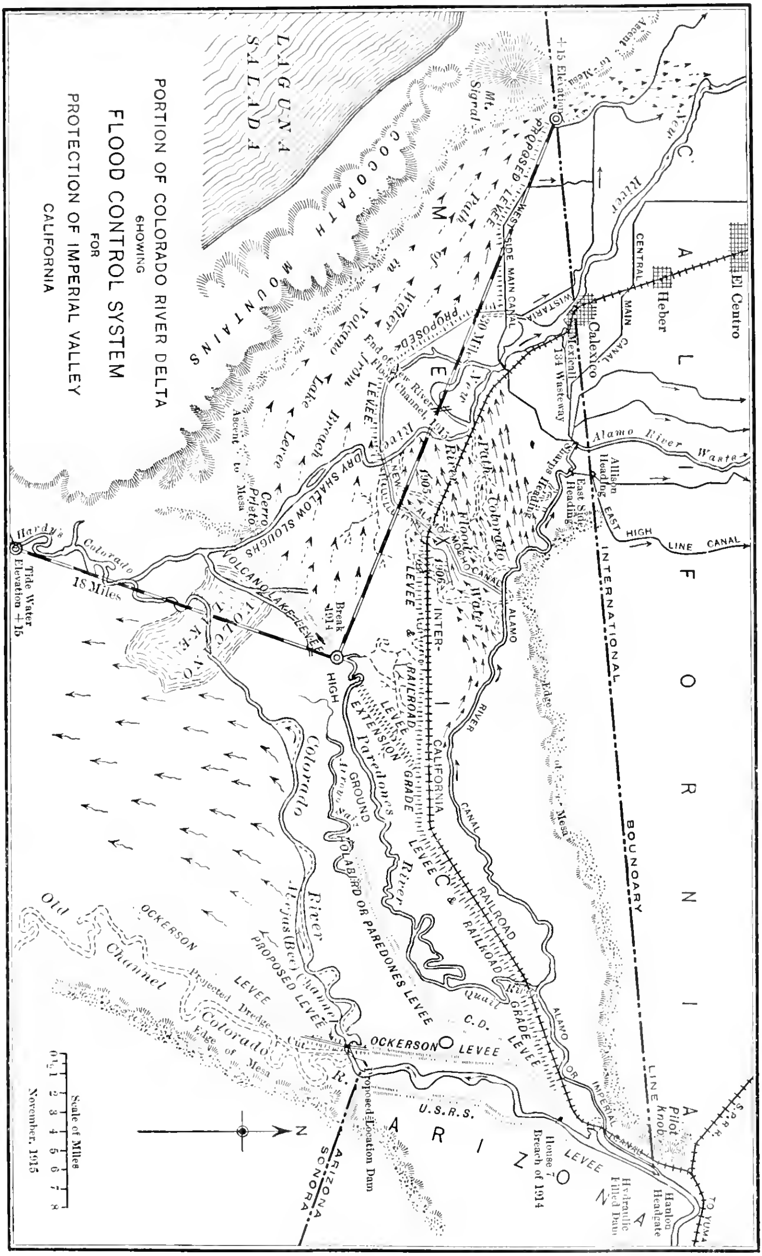

PORTION OF COLORADO RIVER DELTA
SHOWING
FLOOD CONTROL SYSTEM
FOR
PROTECTION OF IMPERIAL VALLEY
CALIFORNIA
LAGUNA SALADA
COCOPAH MOUNTAINS
CALIFORNIA
MEXICO
ARIZONA
SONORA
INTERNATIONAL BOUNDARY LINE
El Centro
Heber
Calexico
Mexicali
Hardy's
Tide Water Elevation +15
18 Miles
VOLCANO LAKE LEVEE
DRY SHALLOW SLOUGHS
OCKERSON LEVEE
OCKERSON LEVEE
PROPOSED LEVEE
PROPOSED LEVEE
WEST SIDE MAIN CANAL
HIGH LINE CANAL
EAST SIDE HEADING
ALAMO CANAL
INTER-CALIFORNIA RAILROAD
RAILROAD GRADE LEVEE
LEVEE EXTENSION
HIGH GROUND
Pilot Knob
Hanlon Headgate
Hydraulic Filled Dam
TO YUMA
S.P.R.R.
U.S.R.S.
Proposed Location Dam
House 7 Breach of 1914
Scale of Miles
0 1 2 3 4 5 6 7 8
November, 1915

FIG. 1.

adopted, and the damage was readily repaired. In this case there was no danger of destructive flooding, as the river did not overflow the banks, and there was no head of water against the levee. The breach was caused by erosion of the bank and levee which could have been prevented by temporarily diverting the current away from the bank with jetties, until rock revetment at the toe of the levee could be placed.

The breach at "House 7", as the point is designated, was not due to any defect in the location or construction of the primary line of defense, but solely to failure to maintain the line. It was an administrative, not an engineering failure.

During the flood of 1914, the long stretch of bank between the levee and the river was cut away, up to the toe of the levee, but the latter was saved intact by dumping large quantities of rock at the foot of the slope, which filled the trench scoured by the current, and formed permanent revetment. A railroad track on the levee, and an inexhaustible supply of rock in a quarry at Hanlon Heading, near by, facilitated this method of revetment.

To make this line of defense impregnable, it is necessary only to reinforce the levee wherever bank cutting occurs, doing the work from year to year as conditions call for it. Assuming that reasonable attention is given to the matter, and that ordinary diligence in maintenance is observed, the protection afforded by the levee south of Hanlon Heading is sufficient. When thoroughly revetted down to the scour line, the levee cannot be broken by flood.

Head-Gate Foundation.

The only weak point in the line is the head-gate in the Alamo, or Imperial Canal, at Hanlon Heading; and the weakness there is due to the character of the rock foundation, which is not what it was assumed to be by the builders of the gate.

Some have held that the location of the gate in a rock spur of Pilot Knob was not necessarily of strategic importance, and that such a structure might be built safely and satisfactorily on alluvial soil, on the Mexican side of the line, using wooden caissons as a foundation.

Without going into the reasons for this proposed change of location of the head-works, which are political and, in the opinion of the writer, not based on engineering considerations, it seems almost self-evident that rock foundation is a vital factor in the construction of a head-gate on the Colorado. This is demonstrated, not only by the failure of the structures lacking such foundations, but by the weakness developed in the foundation of the concrete gate at Hanlon Heading.

The Rockwood gate, constructed of timber in 1905, was built in the alluvial bank of the Colorado River in Mexico, some distance from the channel, to serve the double purpose of first controlling the run-away river, and later becoming the head-gate for the Alamo, or Imperial Canal. The writer is familiar with the design and construction, and all problems connected with that gate, and was on the ground at the very moment when it failed. It is his opinion that it would be difficult to devise, for a structure resting on alluvial soil, a more substantial foundation than was designed for this gate. In other words, the Rockwood gate represents a type of construction as nearly perfect as can be devised, at any reasonable expense, for a structure resting on alluvial silt deposits, and yet it failed.

In building structures, whether of wood or concrete, on alluvial soil, the problem presented to the engineer does not concern strength of material and design to meet the stresses to be put on it, so much as it involves provision to meet the boring action of water in front of and back of the structure, wherever large volumes are dealt with. For several months after it is built, the structure must be watched constantly because of the boring action and the resulting settlement or displacement of filling under and around the wings and curtains. After the settlement of the filling, the structure may be reasonably safe for the head under which it was "cured", but an increase or decrease of the head tends to develop new conditions which may cause damage.

This applies to Imperial Valley generally, but the difficulty is even more pronounced along the banks of the Colorado, where the land has been built up in strata of sand and silt containing more or less decayed vegetable matter, and where the structure is subject to extreme variations of pressure induced by a rapidly fluctuating river.

The Rockwood gate failed, not from the pressure of earth or water it was required to withstand, but from the boring which took place in front of the front curtain. In spite of the extended upper curtain, and the extensive apron built in front of the structure, this boring continued to develop with the increased volume of water put through the gate, until it had entered under the front end of the structure and lifted it bodily from its anchorage.

This might have been avoided had rock and other material been available in quantities sufficient to prevent this scouring, but the same condition might have developed at any time under either wing of the structure, or from leakage through the silt puddle work when the structure was later suddenly subjected to increased water pressure. This is especially true because, during a recent seismic disturbance, the silt puddle work around most of the secondary structures in the canal system was disturbed.

The concrete gate at Hanlon Heading has been in use since November, 1906. During this time it has served its purpose as a regulator in the Imperial Canal, but with excessive operating costs, due to its design, and, as recently discovered, with considerable danger to the system during high water. The cost of handling drift through the gate has been excessive, and represents the largest operating expense of the river division, outside of the dredging of the canal. The enormous quantity of drift which the river brings into the intake and lodges against the gate has, in the past, blocked the openings to such an extent as to cause temporary water shortage in Imperial Valley.

As a partial solution of the drift problem, a sheer boom was built across the mouth of the intake during the season of 1912, and most of the surface drift has been handled successfully at that point, rather than at the gate itself. The submerged drift continued to give trouble by lodgment in the gate tunnels until a new section of the gate was built during the spring of 1913. The construction of the new gate was such as permitted the free passage of submerged drift. The level of the sill of the Hanlon Gate, as originally constructed, was calculated to pass all the water required for irrigation in Imperial Valley without a diversion weir in the river. The width of the structure was in excess of what was calculated for carrying water in the canal alone, as it was presumed that the gate would play a part in turning the water of the Colorado River back to its old channel. The sill proved to be sufficiently low to allow the desired quantity of water to pass over it into the Imperial Canal until 1912; but, because the average bottom of the river was lower during the low-water period than previously, owing to the new route which the river takes to the Gulf through the Bee River, and because the demands for water during the low stage of the Colorado River were greater than was calculated, the sill of the gate proved to be too high.

During the summer of 1910 it became necessary to construct a rock weir across the Colorado River, in order to divert sufficient water through the gate to meet the demands. The necessity for the weir arose from the fact that the canal above and below the gate had silted, but since then it has developed that, even with the intake clear to the elevation of the former sill of the gate, sufficient water could not have been diverted at the low stage of the river.

It became evident that a second diverting weir would be necessary, or that the sill of the gate would have to be lowered. A permanent weir in the Colorado River was out of the question. The property of the California Development Company was in the hands of a receiver, and he could not do permanent work of this nature; neither were the funds in his hands sufficient to meet the costs of a permanent weir at this point. A temporary weir, such as was constructed in 1910, would not have served the purpose, on account of the heavy maintenance expense and the danger to the levees and banks on both sides of the river, caused by its presence during high water.

It was decided, therefore, to lower one 25-ft. section on the north end of the concrete gate, and in the new opening the radial gates were replaced with a sliding gate of the Stoney type. After the coffer-dams were in place and the excavation work had commenced, a flow of water developed around the end of the coffer-dam connecting with the original concrete gate, and thence inside the coffer-dam. A careful investigation disclosed the fact that the original gate did not rest on solid rock, but on a very inferior grade of decomposed granite, full of soft seams, all of which were water-bearing. This decomposed material had been scoured from under the floor of the old concrete gate until the piers and more than one-half of the original floor had scarcely any foundation left. Holes bored by the water under the original floor were in some places as deep as 8 ft. below the floor line. It is a marvel that the gate had stood, against a head of water varying in the summer from 13 to 16 ft., on the little remaining foundation, through which there must have been constantly a great quantity of percolation. Had this condition been allowed to remain through one, or perhaps two, additional flood seasons of the Colorado River, the remaining foundation would certainly have been scoured out, causing the complete failure of the structure. This condition under the north side of the gate was corrected in that portion enclosed within the coffer-dam by a series of concrete curtain-walls running down in front and below the structure to serve as cut-off walls. The foundation was refilled with concrete, and a strongly reinforced concrete floor was laid on top. This section of the structure has since been used exclusively during high water, eliminating the danger of failure to a great extent. The weakest point in the primary line of defense, in the writer's opinion, is still the unused portion of the Hanlon Gate. The weakness would be many times greater if the structure was in the alluvial deposits along the river bank in Mexico, where even an inferior grade of rock foundation is not to be had.

Temporary Diversion Weir.

Mention has been made of the temporary rock weir built across the Colorado River in the summer of 1910, and the statement has been made that such a weir would not serve as a permanent structure. H. T. Cory, M. Am. Soc. C. E., states that even the comparatively small quantity of rock dumped from the trestle to form this weir was not undermined, and did not settle, except to a slight extent and in a few places, with the summer floods of 1911 and 1912.

In building the weir, 1 822 cu. yd. of rock were used, at a cost of 60 cents per cu. yd. The total cost of the weir, including this rock, plus the cost of providing a trestle and maintaining it during its life, amounted to $32 350. The greatest head developed by the weir was 3.4 ft. on October 19th, 1910, when the Colorado River discharge was 5 000 sec-ft. The only way that this maximum head was developed and maintained was by constant expenditure of money and labor in obtaining rock and filling in the low places along the weir as they developed. In addition to this maintenance cost on the weir itself, there was the cost of maintaining the rock abutments on both ends of the weir up and down stream. The Arizona abutment was maintained at great expense some time after the weir was removed, in order to prevent cutting into the Arizona shore and injury to the levee constructed by the United States Reclamation Service. All this goes to show that such a weir is not practical, from a maintenance point of view alone.

In March, 1911, the trestle was removed and all maintenance work on the weir itself was stopped. For some time previous to March, 1911, no maintenance work was done because of instructions from the War Department that no more material should be dumped into the Colorado River. The average elevation of the crest of the weir was about 108 in October, 1910, and 105 in February, 1911, showing that as soon as the maintenance work was stopped, the rock began to slip down stream. In January, 1913, further investigation of the weir was made, and the elevation of the crest of the rock was found to be below 94, there being only a few places where the rock could be reached by sounding.

Very little good was effected by the weir in the way of securing sufficient discharge through the concrete gate at the low stage of water, after the summer of 1911. It is true that the piling butts, which remained after the blowing of the trestle, caught and held a great quantity of drift, and developed several sand bars in the location of the old weir, but this obstruction caused only a slight increase in the head at the intake.

Sole dependence for a sufficient water supply for Imperial Valley was placed on the hydraulic dredge *Imperial,* operating below the head-gates, and on the dredge *El Centro,* operating above the head-gate in the intake canal and in the Colorado River channel, controlling sand bar obstructions, etc.

The actual computed yardage of solid material moved by the dredge *Imperial* from the canal below the head-gate in one season's operations is equal to just one-tenth of 1% of the solid matter discharged through Hanlon head-gate in the same interval, but it is also a fact that it was just this one-tenth of 1% of solid matter which had heretofore blocked the canal delivery below the head-gate before the dredge was put in operation.

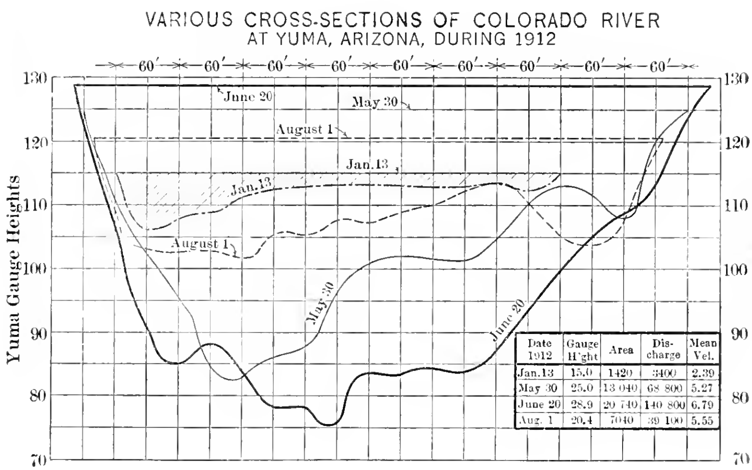
The major part of the one-tenth of 1% of solid matter removed by the *Imperial* was shingle, ranging from 1-in. rock to ¼-in. gravel, and sand ranging from gravel down to materials which are retained on a No. 10 mesh screen. It was the discovery of this fact that led to the successful operation of the Hanlon Heading, from the time of the entire removal of the rock weir in 1911 up to the present. This grade of material has been removed systematically every year since the dredge has been in operation, thus permitting the bed of the canal below the head-gate to be maintained at an elevation which gave a sufficiently low water surface in the canal at all times. All other sands and silts not removed by the *Imperial* are carried down the canal in suspension.

The fact that there was deposited below the head-gate, at times when the velocities in the intake exceeded 6 ft. per sec., material of a kind which could not be carried down the canal by the velocities below the head-gate, which are never greater than 4 ft. per sec., led to the discovery of a means by which a hydraulic-fill dam could be placed across the Colorado River at a point directly below the intake, to serve as a means of diverting sufficient water into the Imperial Canal, should the necessity ever again arise. This time did arrive during the summer of 1915, because of the combination of an exceptionally low Colorado River during August and September, and an exceptionally great demand for water in Imperial Valley, due to the large increase in irrigated acreage over the previous years.

A study of the cross-section of the channel of the Colorado at Hanlon Heading, and at the gauging station of the United States Reclamation Service at Yuma (Fig. 2), shows that the Colorado—like other rivers forming deltas—scours and refills its channel bed with the increase and decrease of quantities of water, and that a direct relation exists between the character of the materials forming the bed and the velocities of the water. For example: The river bed is scoured to an elevation of 85 at Yuma, Ariz., by a discharge of 140 800 sec-ft., whereas it is refilled to an elevation of about 110 by a discharge of 3 400 sec-ft. The only reason that the bed does not scour deeper than an elevation of 85, with a discharge of 140 800 sec-ft., is that at that depth the materials constituting the bottom are so heavy that the velocities, registered as 6.8 ft. per sec. for this discharge, will not move them. It follows that, in refilling the bed, the materials are graded as to weight, and deposited in direct relation to the velocities. It also follows that the refill in all cases is in strata of materials decreasing in weight as they approach the elevation corresponding with the lesser velocities.

Though this is by no means a new discovery, the experience with the dredge *Imperial* below the head-gate served to bring out more strikingly the real relations between the weights of materials and the velocities, and showed a way to make a practical use of this knowledge.

The scour line of the bed of the Colorado at Hanlon Heading is at an elevation of about 84. The ladder of the 10-in. suction dredge *El Centro,* operating in the river and above the concrete heading, was designed so as to make it possible to pump from an elevation of 80 when the surface of the river was 110. The materials in this area below the scour line had withstood the scouring effects of velocities as high as 7 and 8 ft. per sec. Those materials, when brought to the surface and deposited in the water where the velocity had decreased to 2 and 3 ft. per sec., due to falling discharge, were certain to stand in the position placed by the discharge of the dredge, making it



Date 1912	Gauge H'ght	Area	Dis-charge	Mean Vel.
Jan. 13	15.0	1420	3400	2.39
May 30	25.0	13 040	68 800	5.27
June 20	28.9	20 740	140 800	6.79
Aug. 1	20.4	7040	39 100	5.55

FIG. 2.

possible to construct a hydraulic-fill dam under the water of a running stream varying in depth from 2 to 15 ft.

HYDRAULIC-FILL DIVERSION DAM.

On August 12th, the *El Centro* commenced the construction of such a dam below the intake, and in 14 days had raised the fill to an elevation of 12 in. above the water surface three-fourths the distance across the river. This fill reached from the Arizona bank of the river to within 250 ft. of the California shore, or a total length of fill of 650 ft. Due to the constriction of the channel during this period, a head of somewhat more than 1 ft. was developed, which resulted in a corresponding increase in velocity through the remaining opening. The velocities resulting from this head became as great as those developed during flood discharge of the river, and consequently material pumped from below the scour line could no longer be deposited in the dam, with any degree of economy, without adopting some method of decreasing the velocities. In closing the last 250 ft., therefore, a great quantity of brush and sacks filled with gravel was used.

The California shore had in years past been thoroughly revetted with a blanket of rock 25 ft. thick, making it safe to drive the channel directly against it, where the final closure was made. It is true that before the final closure took place the terrific velocities along the California shore scoured even the rock revetments to a certain extent, due to the large percentage of fine material composing the revetment, but a careful study of records, and the materials themselves, indicated the presence of a sufficient quantity of large rock in the revetment to make it a dependable protection against the cutting of the river on this side. The dam was commenced on the line of the old rock weir on the Arizona side, and the rock abutment served as protection there.

The closure of the final 75 ft. of the channel represented the most difficult operation in the construction of the dam, and the means devised for making this closure again demonstrated the advantage of close observation of the action of a river when left to itself, and the application of the results of this study in a practical way.

From August 12th to September 12th was the period of principal construction. The time subsequent to September 12th was spent principally in making the final closure and in maintaining the structure. On August 12th the river was discharging 8 800 sec-ft. Of this discharge, 2 529 sec-ft. were flowing into the Imperial Canal, all the gates in the heading being fully opened. The requirement for irrigation in Imperial Valley was 5 000 sec-ft. By September 12th, the river discharge had dropped to 4 000 sec-ft. During this period of 30 days there was used in the construction of the dam:

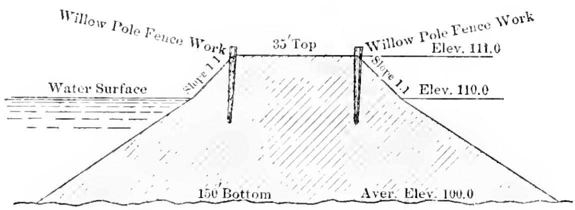
40 000 cu. yd. of sand and gravel fill, at 2.7 cents per yd.	$1 080.00
21 300 burlap and canvas sacks, at 3 to 6½ cents each	1 140.00
450 cords of willow brush and poles, at 73 cents per cord	328.50
800 lb. of wire	32.00
Cables and clamps	100.00
Labor, filling and placing sacks, carrying and placing brush, poles, etc.	2 000.00
	$4 680.50
Plus 10% for superintendence and tools, etc.	468.05
Total	$5 148.55

Since September 12th there has been an additional expense of $2 000 for raising and strengthening the dam by dredging, and for labor in closing and opening the dam, and general maintenance of the structure, making the total final cost $7 148.55.

The following methods were used in constructing the major part of the dam: Pumping was commenced on the Arizona side, the dredge pontoon being some distance above the site of the dam, and the discharge being carried astern through a 10-in. pipe floated on pontoons to the fill. Owing to the admixture of lighter grades of material encountered in burying the suction pipe to the scour line depth, and to the subsequent caving in on the suction of the surface materials when the depth was once reached, the base of the dam, in a great many places, became as wide as 150 ft. The heaviest materials pumped—in some instances stones and cemented adobe chunks 6 in. in diameter—remained exactly where placed, but the lighter sands and gravel were carried by the current some distance down stream before they lodged in permanent position. When a point near the water surface was reached with the fill, the conservation of the material was made possible by constructing brush fences to help retain the material at the slope required. (Fig. 3.) By this process the structure was carried across the stream to the point of final closure. Three re-runs across were made later with the dredge, bringing the crown to an elevation of 114, which is about 5 ft. above the water surface of the river when 5 000 sec-ft. are passing into the canal. (Figs. 4 and 5.)

On September 10th, 2 300 sec-ft. were passing through the opening in the dam, and 3 300 sec-ft. had been diverted into the Imperial

Canal. The head on the dam was 2 ft., and the resulting velocity through the remaining opening was 8 ft. per sec. The bottom of the opening had been paved with about 10 000 sacks, filled with gravel pumped by the dredge, and stoutly tied, decreasing the depth to about 5 ft., and thereby preventing scour. Great quantities of sacks were used in protecting the Arizona end of the opening, the California shore, as before stated, being protected by its rock facing. Additional sacks were used in forming the overpour riffles as fast as the head developed. A great number of the sacks were of no avail, either because of their lodgment in the wrong place, or because of breaking and washing out; and, throughout the whole process, constant replacements were required because of the boring effects at the toe of the sack riffles, causing the embedding of the sacks.



CROSS-SECTION OF COMPLETED DAM

FIG. 3.

In paving the bottom, the point above the opening at which the sacks should be dropped in order that they might lodge on the bottom in the proper place, was determined by constantly experimenting with sacks thrown overboard attached to wires, thus making it possible to locate the sack when it had finally settled by following the line of the wire. Only those filled with the coarsest shingle and gravel and of greatest weight would remain in position and withstand the velocity for any length of time.

In the final closure, when the bottom had been protected carefully, cables were stretched across, securely anchored to deadmen on the California side and in the body of the dam on the Arizona side. The first cables used were of $\frac{3}{4}$-in. plow steel, but proved to be too light when maximum strains were put on them. After one failure in making the closure, due to breaking the cable, a double strand of $1\frac{1}{4}$-in. cable was used for the lower run.

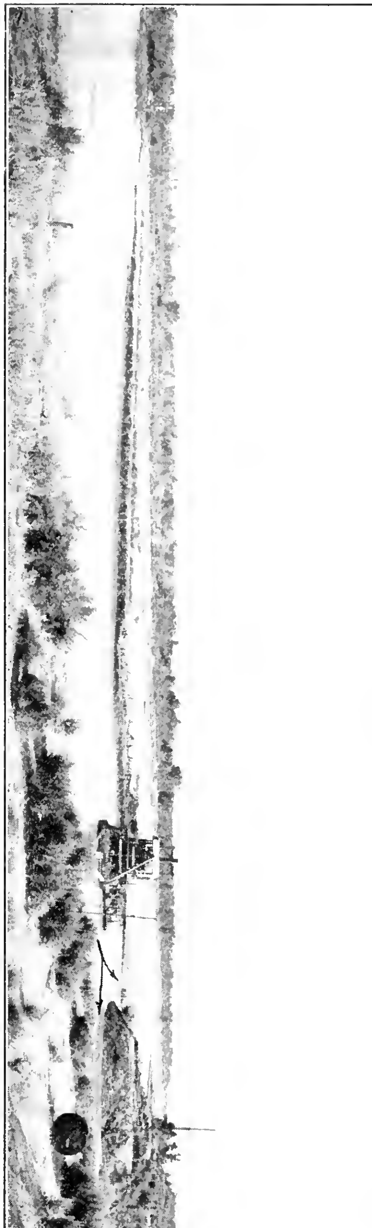


FIG 4.—HYDRAULIC-FILL DAM IN COLORADO RIVER AT HANLON HEADING, FROM ABOVE ON CALIFORNIA SHORE, SEPTEMBER 11TH, 1915.

FIG. 5.—HYDRAULIC-FILL DAM, HANLON HEADING, FROM ARIZONA SHORE TOWARD ALAMO INTAKE CANAL, AUGUST 29TH, 1915.

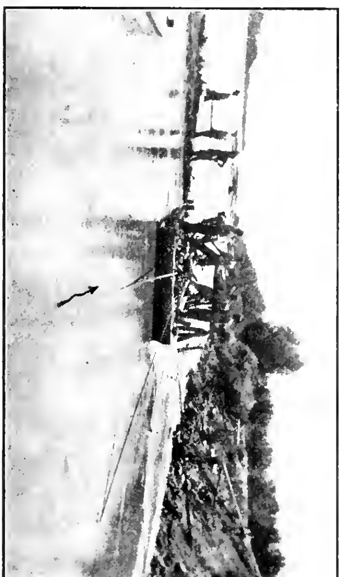


FIG. 6.—CLOSING FINAL OPENING, HYDRAULIC-FILL DAM, HANLON HEADING, SEPTEMBER 11TH, 1915.

Willow poles were cut from the Arizona and California shores near by, where the supply is abundant. The poles were 30 ft. long, the diameter of the large end being 10 in., and the small end tapering to 5 or 6 in. By the skillful use of barges and lines working above the openings, these poles were maneuvered with the current in such a manner as to cause their large ends to lodge against the cable stretched across the opening above the water surface, while the small ends rested on the bottom at an angle of 30°, much as a drifting snag will lodge in a swiftly running stream when the heavy end is dragging the bottom and the upper end encounters a surface obstruction of trees or other large drift. (Figs. 6 and 7.) These poles were placed against the cable, in this manner, with enough space (sometimes 4 or 6 in. between them) to give sufficient strength to the structure and yet not decrease the area in the opening so greatly as to produce much additional head. When all the poles were in place, large bundles of willow brush were made up, weighted heavily with sacks, and rolled into the water from the barges, anchored some distance above the opening, in such manner as to cause them to strike the bottom of the channel and roll against the lower ends of the poles. As additional bundles were thrown in, the pressure against the poles increased, forcing them to bend, until in some instances, before final relief to the strain was obtained, the upper parts of the poles were standing vertically, and the lower sections were bowed to the extreme. Green poles were always chosen because of their flexibility. (Fig. 8.)

The placing of the bundles of brush was carried on in sections only, and only in sufficient quantity to decrease the velocity through the section to a point where material deposited by the dredge could be retained in place. In this manner the strain against the poles in any section of the opening was of short duration, as the dredge would give relief in a few hours by extending the dam above. Of course, a great many sections failed during the work, because of poles breaking, but means were at hand for speedy replacement when such accidents occurred. Because the impounded area above the dam was so great as to require several hours to increase its elevation when flow through the opening was reduced, the extra heads created by stoppage with the brush were not felt on the poles to any great extent before the dredge had given relief.

After numerous local failures, due to small freshet rises in the river, and the breaking of cables and poles, the opening was entirely closed on September 20th, the head then being 6.4 ft. (Figs. 9 and 10), and the discharge of the river, measured at Hanlon Heading, 2 958 sec-ft. Between September 20th and 27th the river discharge fluctuated between 3 000 and 4 000 sec-ft., all of it being required for irrigation in Imperial Valley. On September 27th, because of advance notice from Needles of a rise in the river, the dam was cut at a place provided, and all water, with the exception of 4 000 sec-ft. was passed through into the channel of the Colorado River below. The waters thus let through the dam were forced into the California bank below by local obstructions, so that on October 2d the opening in the dam was again closed, and all the water was diverted into the Imperial Canal. The discharge of the Colorado River on October 2d, as measured at Hanlon Heading, was 4 406 sec-ft. The second closing head was 8.2 ft. (The closing head of the Hind rock-filled dam, on November 4th, 1906, was 15.8 ft., with a river discharge of 9 275 sec-ft.*)

The 36 hours following the second closure were spent in clearing obstructions in the channel immediately below the dam, and in providing a new waterway to train the flow away from the California shore. On the evening of October 3d, the dam was again cut at the place provided, because of a rise in the river in excess of the water requirements in Imperial Valley. During the period from October 3d to the present writing, the opening in the dam, 100 ft. in width, has been left, and through it the discharge has been as great as 8 000 sec-ft. In constructing the dam, provision was made for accommodating the freshet discharges of the river, which commonly occur during October and November. These sections will be sacrificed only as required, because of the fact that during December and January the discharge of the river commonly reaches the minimum, and this being a year of exceptionally low water, it is quite likely that the irrigation requirements of Imperial Valley will again make it necessary to close the dam fully. Entire removal probably will be advisable in March or April, 1916, and by that time it will have fulfilled its purpose as a means of diverting sufficient water to meet the irrigation demands of the Valley. In any event, the annual flow period of May and June,

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* "Irrigation and River Control in the Colorado River Delta," by H. T. Cory, M. Am. Soc. C. E., *Transactions*, Am. Soc. C. E., Vol. LXXVI, p. 1204.

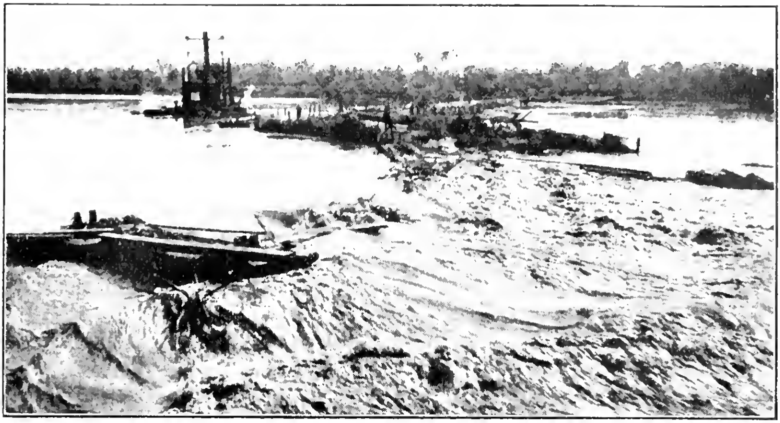

FIG. 7.—HYDRAULIC-FILL DAM, HANLON HEADING, NEARING COMPLETION, SEPTEMBER 4TH, 1915.

FIG. 8.—REMAINING OPENING IN HYDRAULIC-FILL DAM, HANLON HEADING, SEPTEMBER 17TH, 1915.

FIG. 9.—FINAL CLOSURE FROM BELOW HYDRAULIC-FILL DAM, HANLON HEADING, SEPTEMBER 20TH, 1915.

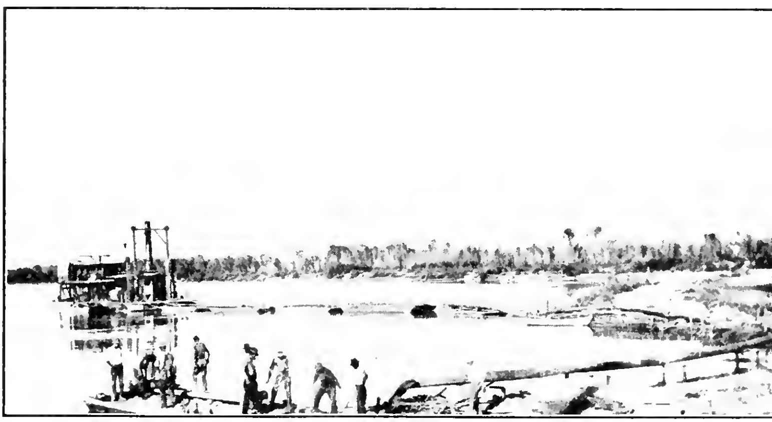

FIG. 10.—DREDGE, *El Centro*, PUMPING IN FINAL CLOSURE, HYDRAULIC-FILL DAM, SEPTEMBER 20TH, 1915.

1916, will remove the structure entirely. If the conditions which develop before this time should require it, the whole structure could be speedily removed by mining, as it is composed entirely of brush, sacks, and gravel, with the exception of a few willow poles driven with the aid of a jet from the dredge. The structure contains absolutely nothing of a permanent nature.

The experience in building this dam has developed naturally a great many improvements which would be adopted in a second construction of similar nature; so that such a dam could be built in a much shorter period and with much less expense. For instance, by constructing an aerial tramway, anchored to towers on each bank of the river, dredge lines can be carried across the stream during its flood, thus enabling the dredge to venture into the river during much higher water, resulting in earlier completion of the work. The ladder of the dredge *El Centro* is to be lengthened 15 ft., enabling it to pump material at a greater depth below the scour line. These two improvements alone will permit the commencement of the dam while the river is discharging 56 000 sec-ft., and will permit the complete diversion of a river carrying 15 000 sec-ft. if necessary. More economical use of sacks and the labor attending can be achieved by a more general use of cable and pole manipulation in closing the final opening. Fewer accidents in the final closure will be assured by anticipating the material requirements in time to accumulate sufficient quantities of poles and brush. By lengthening the pontoon and pipe line of the dredge, thus providing an increased radius of operation, a large supply of material suitable for construction can be obtained.

Closure of Bee River.

The application of a hydraulic-fill diversion dam as the fundamental factor in the closure of the Bee River break in the first line of defense is easily recognized. It is not possible to use the hydraulic fill to close the break itself and to force the river waters back into the old channel of the Colorado, because, in the vicinity of the Bee River break, the Colorado has never maintained a permanent channel bed for any length of time. Each flood, instead of scouring out a well-defined bed and refilling this with material suitable for dam construction, has widened and changed its channel to accommodate the larger volumes of water, deriving its increased sectional area from width, rather than from depth. Very seldom is the river channel at the end of any flood season in exactly the same location as in the beginning, and for this reason there is no certainty that proper materials for constructing a hydraulic-fill dam at Bee River could be found. On the other hand, in the stretch of river channel from Yuma to a point 4 miles below Hanlon Heading, the river has always, within the memory of man, remained practically in the location it is in to-day, and the successful construction at any place within this radius is assured.

Engineers acquainted with the Colorado Delta agree that the final solution of the problem of control must be the restoration of the river to its old channel. Objections to that plan, which have been raised, are political, and do not apply to the soundness of the plan considered solely from an engineering standpoint. The inexpediency of doing any work of that magnitude in Mexico, until the rights and privileges of citizens of both countries in the matter of use of the river have been readjusted and defined, may be conceded.

There is no longer the imminent menace of disaster to the Imperial Valley canal system that made the closure of the Bee River breach in 1910 apparently an emergency job of vital importance. Construction and adequate maintenance of the line of levees from the old river bank to the west end of Volcano Lake, together with the provision of the interior lines of defense described in this paper, will safeguard the Valley for some time to come.

Therefore, the discussion of methods of closing Bee River and returning the Colorado to its channel close to the Sonora Mesa does not connote advocacy of immediate application of these methods. It is the writer's purpose to show how, in his opinion, such work may be done more readily and cheaply than similar work has been done heretofore, and that the costly processes proposed by some engineers are not essential to successful achievement of the end in view.

Diversion of virtually the entire low-stage flow of the river into the Imperial Valley canals, by the simple and cheap method herein described, removes the first difficulty otherwise to be met in making the closure. It is entirely feasible to make that diversion more nearly complete, and to turn a larger volume of water from the river into the intake and through the gates.

Having taken care of the low-stage flow and dried the river bed at the Bee River break, a levee or earth dam could be constructed across the break with scrapers, in the same way as levees have been built along the river. It would be advisable, in the writer's opinion, to locate this dam nearer the old channel than the site of the dam with which the Government engineers attempted to close the break in 1910-11. The Government levee, from the C. D. levee down to where it was deflected westward near the break, is in fairly good condition, and should be repaired and utilized. A very important factor in the maintenance of the levee is a railroad on the crest connecting with the track on the C. D. levee. That is the vital factor in all levee protection on the Lower Colorado, a fact now recognized by the United States Reclamation Service engineers, who were unable to maintain the levee of the Yuma Project on the Arizona shore until they followed the example of the C. D. levee and placed on it a track connecting with the rock quarry at Yuma.

It is of primary importance that the Government levee be repaired and the track laid in time to extend it over the Bee River dam as soon as the dam has been completed by the scrapers, in order that rock from the Pilot Knob quarry may be used immediately for the revetment of the levee and dam.

Changes in the location of the dam, and of the connecting levee for short distances from both ends, seem advisable. An important reason for the changes is the resulting reduction of head against the dam and levees during overflow from the old channel.

If the work was to be done as originally projected, doubtless a better location than that of the Government levee could be made, nearer the Sonora Mesa, for the reason that the less room the river is allowed for meandering, the greater its velocity and scouring action, and the easier it is to keep it under control. The advantages, in the case of the Colorado River, of a narrow, confined bed, are to be seen plainly in the stretch of river from Yuma down to a point 4 miles below Hanlon Heading, and, in the writer's opinion, they completely refute the theory that the river should be permitted to meander erratically through the delta. The nearer the river course can be made to an efficient hydraulic channel, the simpler becomes the problem of control.

However, the advantages of a new location may be considered as more than offset by the advantages of the utilization of work already done, one of which is the settling, consolidation, and "seasoning" of the sections of the Government levee remaining. The original disadvantage of river side borrow-pits has been minimized to a great extent by the growth of brush and willows that has choked them. As time elapses, that obstruction to the flow of water along the foot of the levee increases. It is essential that, in the restoration of the levee south of the break, the river face shall be blanketed with gravel and the track extended to the south end.

The old channel, from the Bee River diversion some 5 or 6 miles southward, would have to be cleared, and it would be advisable to shorten the course by cutting across some of the bends, thereby augmenting the velocity and the scouring action. In opening the old channel, it would be advisable to use a dipper-dredge, making a double cut for about 6 miles. The writer made a reconnaissance of that region recently, and found outside of the old channel a thick jungle of brush, but no big growth and very few trees. The work of clearing off the lines ahead of a dredge would be inconsiderable, as the dredge could handle the brush. In the old river bed, however, the growth of brush and trees has been very rapid and heavy, and it would be necessary to do thorough clearing, and perhaps it would be advisable to break up root growth and loosen the ground with dynamite.

Given a good, clear start down the old channel, the river in flood would cut an adequate course for itself.

Having a track on the levee from Hanlon Heading to the south end, and the quarry at Pilot Knob to furnish unlimited quantities of rock, loaded directly by steam shovel, revetment could be placed readily wherever danger of bank-cutting under the levee might develop. It would not be necessary to revet the entire levee at once. That work should be done as needed, as part of the maintenance, and spread over a long term of years.

Conclusions.

In discussing the control of the Colorado River, as related to the protection of Imperial Valley, most space has been devoted to describing the hydraulic-fill dam, recently constructed across the Colorado at Hanlon Heading, and the possibility of its further use in future river control.

The writer does not mean to state that such a structure could have been used in stopping the breaks of 1905-06, because of the emergency nature of such work. It is not presumed that such methods can be applied in cases similar to those of the past, where the breaks were stopped while the Colorado River was practically in flood, and where the resulting closing heads were so great as to prohibit the adoption of such means as were used in the recent dam.

Necessity for further emergency work to safeguard Imperial Valley from the flood-waters of the Colorado River no longer exists, and therefore it is possible in the future for the engineer to choose his construction period to conform with the low stages of the river. All the hydrographs of the Colorado River indicate a low period during August, September, December, and January of each year, with very few exceptions, and surely the work can be planned in anticipation of these low stages.

If the engineer will look about him and apply the means at hand in his work, and will study the characteristics of the stream more closely, no such expenditures as have been made in the past will ever again be necessary. The hydraulic-fill dam supplants the trestle and rock-fill dam previously used, which, of course, represents the greatest item of expense in the closure. Not only here is opportunity for great saving of both time and money, but in almost every item of construction is the same opportunity, if the engineer will profit by past experiences and study more closely the examples Nature has provided for him.

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PAPERS AND DISCUSSIONS

THE CHERRY STREET BRIDGE, TOLEDO, OHIO

Discussion.*

By Clement E. Chase, Jun. Am. Soc. C. E.†

Clement E. Chase,‡ Jun. Am. Soc. C. E. (by letter).—The writer believes that Mr. Godfrey's apprehensions concerning the safety of the columns in the viaduct approach of the Cherry Street Bridge would be somewhat allayed if he were to see the completed structure, and thus get a better idea of its proportions and loads. The columns are 13 and 16 ft. long in the 2-ft. square and the 2 by 3-ft. sections, the cross-section in the remainder of the height being very largely increased. They were of square and oblong sections in the original design by the Osborn Engineering Company, and these shapes were retained in the revised design, prepared by Mr. Modjeski, largely for the sake of appearance and economic construction. Circular columns, although excellently shaped as far as strength alone is concerned, would have required expensive form work in this case, particularly at the fascia girder, and would not have corresponded with the architectural lines of the rest of the structure. The columns were of 1:2:4 concrete, very carefully mixed, and well worked in placing, to eliminate voids. Mr. Chase.

There may be doubt whether rectangular ties restrain effectively the rods in the middle of the side of a rectangular column, if it is stressed in compression so heavily that both steel and concrete are needed to carry the loads, but there is no reason why the restraint of the corner rods, even in such a case, should not be just as effective as is that of circular ties on the rods in round columns. In the moderately compressed columns at Cherry Street, the reinforcement, disposed as

* Discussion of the paper by Clement E. Chase, Jun. Am. Soc. C. E., continued from December, 1915, *Proceedings*.

† Author's closure.

‡ Pittsburgh, Pa.

Mr. Chase. it was, is certainly capable of taking care of the small bending stress and any probable shock.

Some of Mr. Godfrey's other criticisms of the detailing in this structure have served to call attention to points which are incompletely or inaccurately presented in the drawings. The main rods of the floor-beams were bent up at an angle of 45° at both ends, and were anchored at one end by a loop into the fascia girder. At the other end they were extended as far out of the half of the girder first constructed as the adjacent old span would permit, which was sufficient to give an ample bond with the second half of the bridge. Also, all corners of columns and beams were chamfered liberally. These points are not shown accurately in the drawings.

The vertical stirrups, to which exception is taken, were spaced so that the shear on the concrete would not exceed 60 lb. per sq. in. Failure by diagonal cracking is resisted effectively by vertical stirrups, even if their exact disposition may not be subject to rigid analysis.

In commenting on the sidewalk bracket connection to the bascule girders, Mr. Godfrey has drawn his conclusions from insufficient information. Details of this connection are not given in the paper. In addition to the two rivets in tension, which are shown in the girder view, Plate XLII—which Mr. Godfrey guessed were all that held the bracket up—there are from five to six rivets in shear, connecting a top horizontal plate to the top flange of the grider. The maximum stress in the top chord of the cantilever bracket is only 15 000 lb.

Mr. Ritchie has added several facts of interest which supplement the writer's account of the operations of his company. The construction of the bridge in two longitudinal halves certainly added greatly to the cost and length of time required to construct the complete bridge. The Cherry Street Bridge was, as he intimates, a storm center in Toledo's political life from its inception until its completion, and hard-won legal victories could not be jeopardized by changes in the plans of construction which otherwise might have been made as their desirability developed.

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PAPERS AND DISCUSSIONS

THE FAILURE AND RIGHTING OF A MILLION-BUSHEL GRAIN ELEVATOR

Discussion.*

By W. R. Phillips, M. Am. Soc. C. E.

W. R. Phillips,† M. Am. Soc. C. E. (by letter).—A brief description of some work brought about through the failure of the foundations at the Union Meat Company's plant may be of interest in connection with the discussion of this paper. The cases were to some extent similar, although the manner of sinking the new foundations was different. Unlike the work at Winnipeg, this was handled entirely from the surface, and was independent of underground conditions, such as water, depth, or material, so long as the latter could be cut by the jet. Mr. Phillips.

The plant of the Union Meat Company is housed in a group of buildings suited to the packing business, and is on the south shore of Oregon Slough, Columbia River, at North Portland, Ore. The principal buildings of the group are the main packing house and the tank house. The former is 122 by 166 ft., and, in its highest part, has seven floors. The latter is 33 by 52 ft., and has four floors.

As designed originally the buildings were to rest on concrete foundations of considerable depth, supported by wooden piles. The piles were properly driven and, after the foundations were built, the spaces between and around the walls were filled with sand dredged from the river. In preparation for the work, wash borings had been made to a depth of 116 ft. below the surface of the ground, where cemented gravel was found. The borings produced nothing to indicate that the ground would not remain stable under the load to which it was to be subjected, and, in this case at least, may be considered as an illustration of unreliability in a test of this class, as the condition on which

* Discussion of the paper by Alexander Allaire, M. Am. Soc. C. E., continued from March, 1916, *Proceedings*.

† Portland, Ore.

Mr. Phillips. the ground depended for its stability was not such as would be readily discovered by wash borings. It was not until the concrete piles for the new foundation were being sunk that the clue was obtained whereby the condition that might be responsible for the subsidence was discovered. During that process a horizontal stratum of dense material about 6 ft. thick, was found at a depth of about 65 ft. below the surface, and, as it happened, just beneath the ends of the wooden piles, which aroused suspicion that the water beneath it was sustaining the ground, and that the water was being slowly displaced by the added load. The correctness of this theory was seemingly demonstrated by sinking a pipe through the dense material. In this pipe water was found to stand at a height of 10 ft. above that of the adjacent slough.

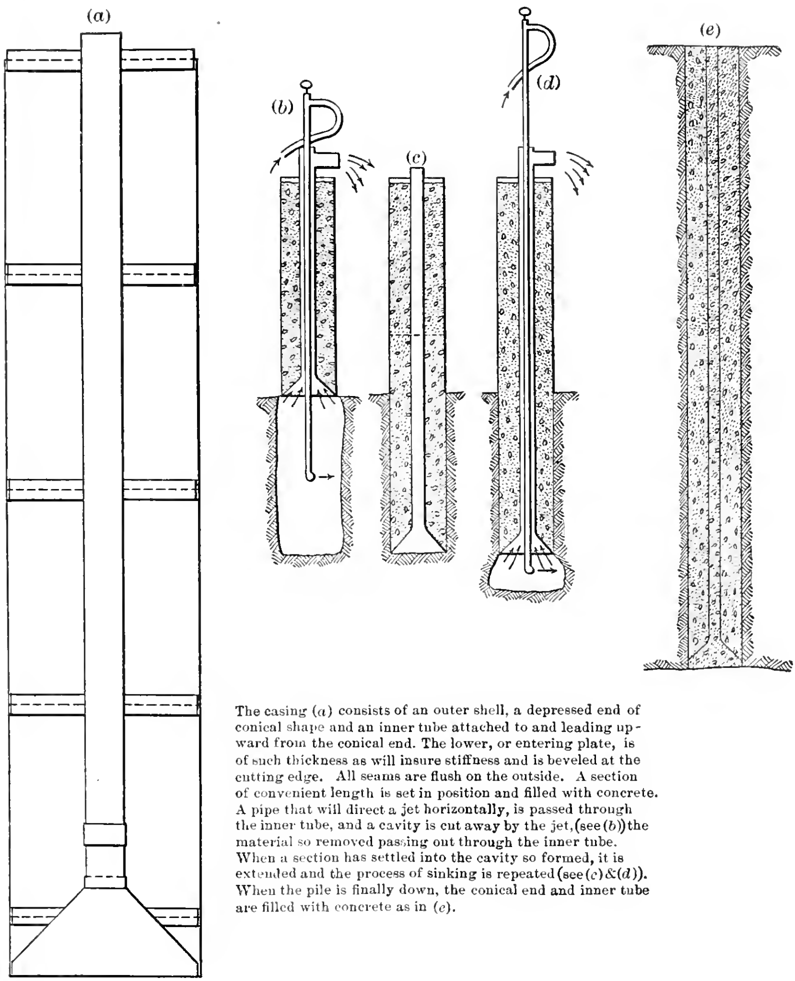
Not until sand was dredged in to fill around the foundation was there evidence of settlement, but with that to start it, it was soon demonstrated that the foundation, as well as the ground around it, was subsiding. A consideration of the conditions led to the conclusion that nothing above the cemented gravel which had been found when making borings could be relied on to sustain the load.

The method adopted for supporting the buildings, and which resulted in finally cutting away and abandoning the original foundations, was to sink concrete piles, in pairs on each side of the old foundation walls, to a bearing on the cemented gravel, and to support the walls and piers on reinforced concrete beams carried by the piles.

The pile as used consists of an outer shell of steel plate attached to an entering piece called the "point", and an inner tube also attached to the point, the space between the outer shell and the inner tube being filled with concrete. The "point" may be considered as a continuous circular gouge with a cutting edge. On the inside, from the cutting edge upward, there is a short conical piece which is also connected to the inner tube and forms an inverted funnel of which the inner tube is the spout. The work connected with sinking the pile is done through the inner tube.

In its application, the "point" and a section of shell of convenient length is set in position, with a guide-frame around it to start it straight in its descent, the annular space inside the shell being filled with concrete. A pipe, which may be moved vertically or rotated at will, with a nozzle which will throw a jet of water horizontally, is inserted in the tube and connected with a pressure system by a hose or other device. Manipulation of the jet bores a hole of sufficient size into which the pile may settle, the material thus removed passing upward and out with the water, by way of the inner tube. When this first section of the pile has reached a level in sinking that makes it necessary to lengthen it, courses are added to the shell, the tube is extended, concrete is placed, and sinking is resumed. The process of extension is repeated until the pile has reached the required depth, and

Mr. Phillips.



The casing (a) consists of an outer shell, a depressed end of conical shape and an inner tube attached to and leading upward from the conical end. The lower, or entering plate, is of such thickness as will insure stiffness and is beveled at the cutting edge. All seams are flush on the outside. A section of convenient length is set in position and filled with concrete. A pipe that will direct a jet horizontally, is passed through the inner tube, and a cavity is cut away by the jet, (see (b)) the material so removed passing out through the inner tube. When a section has settled into the cavity so formed, it is extended and the process of sinking is repeated (see (c) & (d)). When the pile is finally down, the conical end and inner tube are filled with concrete as in (e).

FIG. 21.

Mr. Phillips. then the space beneath is washed thoroughly and concrete is placed there as well as in the tube, making a column of uniform strength throughout its length, and in which the concrete can all have been properly handled and inspected.

Fig. 22 shows two piles being sunk. A man on the highest staging is manipulating the jet pipe with a wrench. The pile to the left has been sunk to a point where it requires to be extended. The inner tube has been lengthened, and courses are to be added to the outer shell. This will then be filled with concrete and the sinking will be resumed.

Fig. 23 shows a pile which has reached a depth where skin friction offers too much resistance to be overcome by the weight of the pile alone, or even by a process which was called the "blow." This consisted in shutting off the water where it is seen escaping above and thus forcing it to find an outlet around the outside of the pile, thereby lessening the skin friction. When the "blow" was not effective, the pile, if on the outside of the building, was loaded as shown, and, if inside, was forced down with jack-screws.

Reinforcement may be used in such portions of the pile as may require it, but it was not necessary in the work described. In this work, 153 piles, ranging in diameter from 22½ to 30½ in. and in length from 108 to 112 ft., were sunk.

For the support of the walls of the main packing house, the piles were put down in pairs, each pair supporting a reinforced concrete beam which was to carry its share of the wall. When the piles required for the purpose were completed, and in advance of the completion of those intended to support the columns inside the building, the beams they were to support were poured, and in due time the weight of the walls was brought to a bearing on them.

Fig. 24 shows the same pile as Fig. 23, the sinking being completed. The lower end of this pile rests on cemented gravel, 116 ft. below the surface. The blocking and jack-screws show the method of holding up the brick walls while the foundation was sinking at the rate of 0.1 ft. per day. At the corner, inside the building, the mate of this pile has been sunk. A hole will be cut through the foundation, below the surface, and a reinforced concrete beam will be built on the two piles.

Fig. 25 shows one of several cracks in the walls of the building caused by the tendency of the blocking to roll. Such fractures had to be closed up after the building had been brought to a state of rest. After piers of brick set in cement mortar had been substituted for the wooden blocks and wedges, there was no further tendency to roll.

During the progress of the work this building had been sinking constantly, but at rates that varied according to the distance from one corner of the building on the end nearest the slough, which had remained stationary. When, finally, the walls were brought to rest on the new foundation, the subsidence at some points amounted to fully 2 ft.

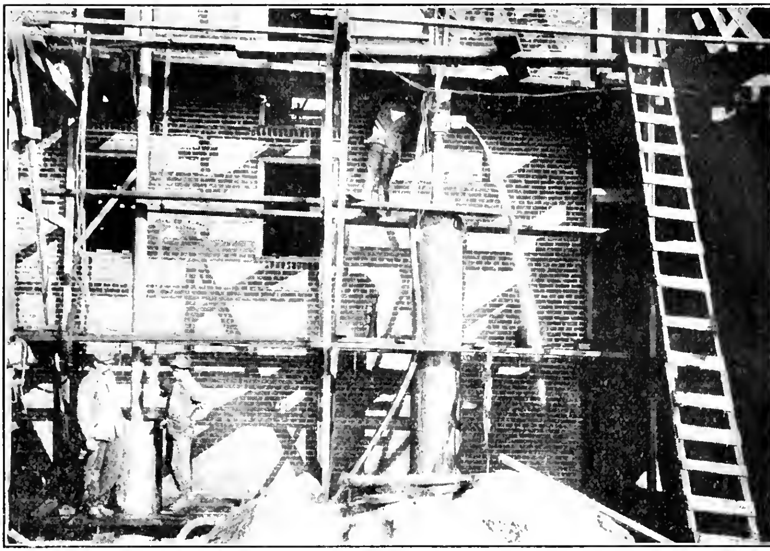


FIG. 22.—METHOD OF SINKING PILES, UNION MEAT COMPANY'S PLANT, NORTH PORTLAND, ORE.

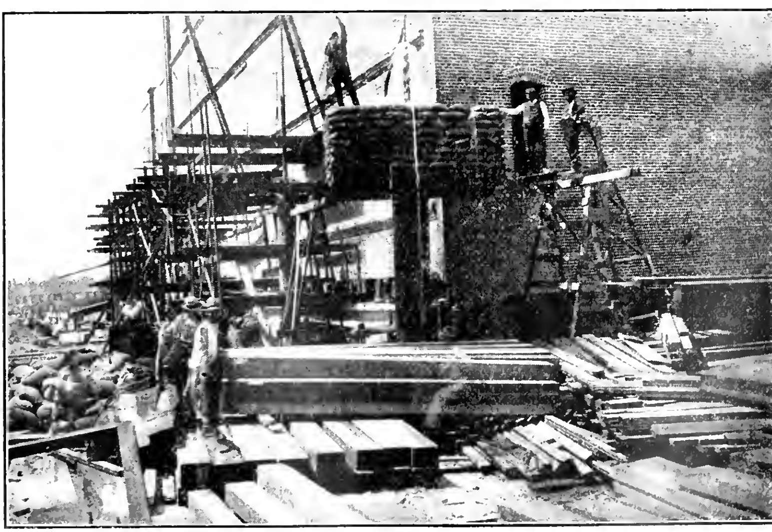


FIG. 23.—METHOD OF FORCING A PILE BY LOADING.

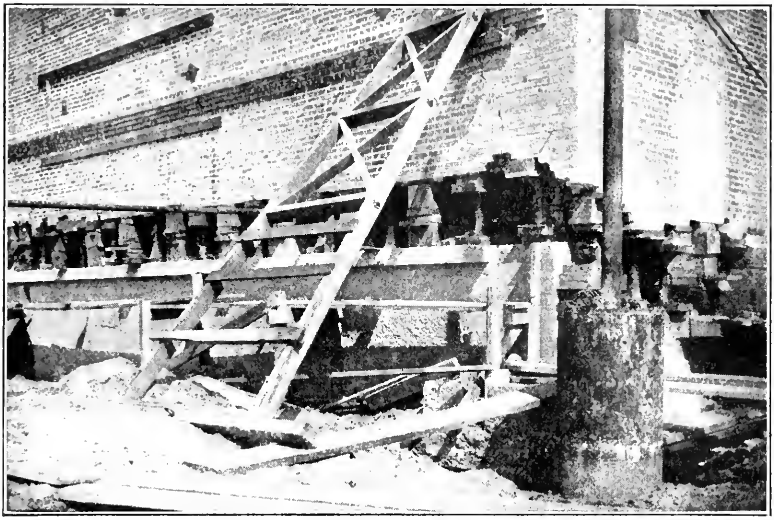


Fig. 24.—Same Pile as Shown in Fig. 23, After Sinking was Completed.

Fig. 25.—Crack in Wall of Building Caused by Tendency of Blocking to Roll.

The columns supporting the floors of the three departments of the main packing house were in three rows in each department. To carry these, two intermediate rows of piles were sunk in line with the original piers, and reinforced concrete beams resting on the intermediate piles carried the three columns in alignment with them. Mr. Phillips.

The tank house, being a lighter structure, was handled in a different way. The concrete piles for it were set away from the old foundation, and on these, continuous beams were poured. The building was moved over to the new foundation.

The work of erecting the buildings had progressed simultaneously with that of the new foundations. That it might be maintained in as nearly a level condition as possible, the walls and columns had been carried on jacks and oak wedges which were kept constantly adjusted. In spite of the care used to prevent it, the walls were badly cracked, and required considerable repairs.

There is no intention to convey the impression that there were no difficulties in sinking the piles, but such difficulties were readily overcome. It was seldom that a pile would follow the jetting as it proceeded. Instead, a cavity of some depth usually had to be washed out beneath, into which the pile would sink in due time. In general, the first 50 ft. or so of sinking was comparatively easy; but beyond that depth, in most cases, more or less urging had to be resorted to. If, however, larger piles had been necessary, or if a greater penetration had been required, or both, the work could still have been accomplished without undue difficulties.

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PAPERS AND DISCUSSIONS

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A STUDY OF THE BEHAVIOR OF RAPID SAND FILTERS SUBJECTED TO THE HIGH-VELOCITY METHOD OF WASHING

Discussion.*

By James W. Armstrong, M. Am. Soc. C. E.

James W. Armstrong,† M. Am. Soc. C. E. (by letter).—At the time Cincinnati was considering the question of the omission of wire screens between the filter gravel and filter sand, and before the experiments mentioned in this paper were undertaken, plans were in preparation for the Montebello filters at Baltimore, Md. Mr. Armstrong.

In order to determine whether or not it would be possible to operate the filters successfully without placing wire screens between the gravel and sand layers, a small wooden filter tank, Fig. 38, was built, early in 1913, somewhat similar to that at Cincinnati. It was 3 ft. by 3½ ft. in plan, and 9 ft. deep. The wash-water trough was 5 ft. 6 in. above the bottom of the tank. Wash-water was admitted to the filters through a wrought-iron pipe manifold with 1½-in. laterals 6 in. from center to center. The laterals had $\frac{7}{32}$-in. holes drilled in them 2½ in. from center to center.

The results of the Baltimore experiments practically coincide with those obtained by Messrs. Ellms and Gettrust, and, in connection with their carefully prepared paper, are of interest only from the fact that, in a number of cases, the wash-water was applied at a much higher rate.

The first few runs were made with both gravel and sand in place. The gravel was 14½ in. deep, and well graded between 3 in. and $\frac{3}{16}$ in. in diameter. There was a depth of 24 in. of sand on top of the gravel. It was found that when the wash-water was passed upward

* Discussion of the paper by Joseph W. Ellms, M. Am. Soc. C. E., and John S. Gettrust, Esq., continued from April, 1916, *Proceedings*.

† Baltimore, Md.

EXPERIMENTAL FILTER TANK AT BALTIMORE, 1913.

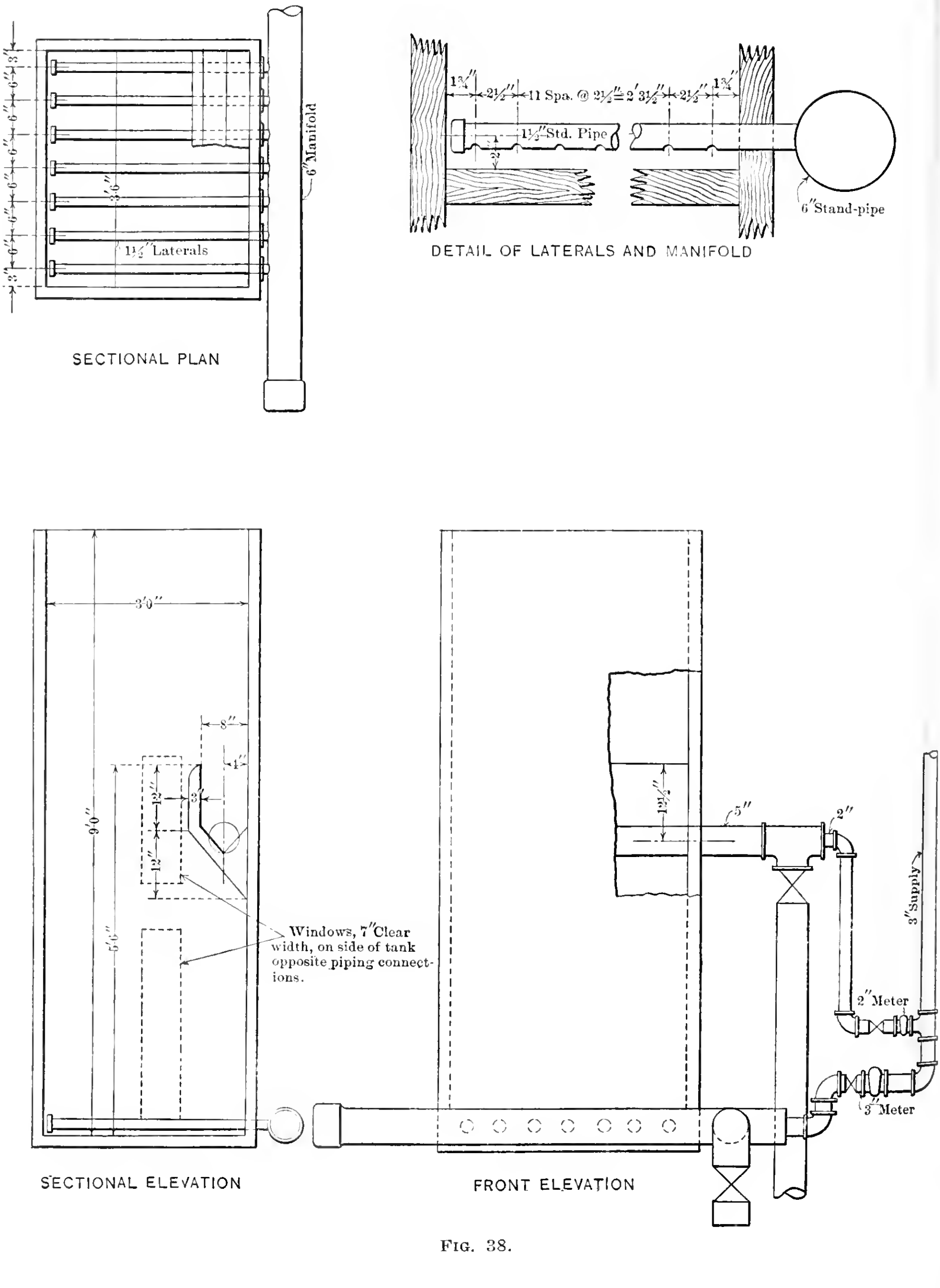

Fig. 38.

TABLE 8.—ACTION OF GRAVEL AT MONTEBELLO FILTERS, BALTIMORE, MD., WITH VARIOUS RATES OF WASHING. DECEMBER 30TH, 1913. Mr. Armstrong.

Series.	Total Thickness of Gravel, in Inches.										Laterals opening upward or downward.	Rate of vertical rise, in feet per minute.	Movement of gravel.
	Passing. 3 in. Retained. 1 in.	1 " 5/8 "	5/8 " 3/8 "	3/8 " 3/16 "	3/16 " No. 10.	3 " 1 in.	1 " 5/8 "	5/8 " 7/16 "	7/16 " 1/4 "	1/4 " No. 10.			
1	8	3	2	1½	0	....	....	....	....	....	Downward	1.51	No movement.
												1.78	No movement.
2	4	1½	1	⅜	1¼	....	....	....	....	....	Downward	4.63	Boiling, in jets, rising about ½ in. extreme cases.
												6.28	Boiling localized but violent, 1 in. extreme cases.
												5.20	Boiling gently—isolated grains rise.
												3.73	No apparent motion except at long intervals.
3	4	1½	1	⅜	1¼	....	....	....	....	....	Upward ..	3.14	Slight shifting of grains.
												3.75	Slight agitation near glass.
												4.92	Boiling general—½-in. rise in extreme cases.
4	....	....	....	....	....	7¾	3	⅞	2⅞	1¼	Upward ..	1.47	No movement.
												3.51	Slight vibration of finer particles.
												3.96	Particles of mica rise—slight boiling.
												4.84	Boiling over entire area—rising 3/16 in.
5	....	....	....	....	....	7¾	3	⅞	2⅞	1¼	Upward ..	2.47	No movement.
												2.99	No movement.
												3.07 / 3.43	Slight sidewise motion.
												3.93	Particles on point of rising.
												4.20	Like gently boiling water.
												5.34	Boils intermittently in spots.
6	....	....	....	....	....	7	2½	1¾	1½	1	Upward ..	4.31	Considerable boiling over entire area.
												4.04	Bubbles in well-defined jets.
												3.94	Bubbling ceases—slight vibration.
												4.23	Bubbles in jets.
												4.26	Bubbling general and violent.
7	....	....	....	....	....	7	2½	1¾	1½	1	Upward ..	4.29	Bubbling begins intermittently.
												4.70	Jetting becomes general.
												5.29	Boiling not severe—3/16-in. rise in extreme case

Mr. Armstrong.

through the gravel and sand at rates giving a vertical rise as high as 2 ft. per min., there was no loss of sand, but when the rate gave a vertical rise of from 2.5 to 2.8 ft. per min., considerable sand was lost.

As the experiments were conducted for the sole purpose of determining the action of the gravel layers under high rates of wash, further experiments with the sand were discontinued, the gravel was re-arranged in several ways, and runs were made with the holes in the manifold system turned toward the bottom of the tank, and others were made with the holes turned upward so that the jets of water impinged directly on the gravel in a direction tending to lift it.

The water for washing was supplied through a 3-in. pipe, directly from the high-service pumps, at a pressure of from 115 to 125 lb. per sq. in. The water was measured with a 3-in. Gem meter, and was applied at rates giving a vertical rise varying from 2 to 6 ft. per min. In no case was there a movement of the top gravel layer sufficient to create any permanent disturbance. After the water had ceased flowing, the gravel returned immediately to its former position, and no evidence existed that there had been any disturbance.

A glass plate in the side of the tank permitted observation of the top surfaces of the gravel and the influence of the water jets on it during the period of washing. Details regarding the depth and size of the different gravel layers, the rate of wash and the effect of the water on the gravel surfaces are indicated in Table 8.

The facts learned from these experiments were sufficient to convince those in charge of the design that the wire screens could be safely omitted, and the Montebello filters were accordingly built without them. There was a depth of 14 in. of gravel and 24 in. of sand in each of the filters.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

THE EFFECTS OF STRAINING STRUCTURAL STEEL AND WROUGHT IRON

Discussion.*

By Messrs. Henry M. Howe, A. C. Irwin, and David A. Molitor.

Henry M. Howe,† Esq. (by letter).—The Society is to be congratulated on this very clear and interesting exposition of the current theory of plastic deformation, and on the reasonableness of the inferences drawn from our present very fragmentary knowledge. This theory, of course, lacks full confirmation, failing, for instance, to explain why, after a heating so gentle as to intensify the hardness caused by the deformation, no traces of the amorphous metal along the slip planes can be detected, though, according to this theory, it ought to be prominent.‡ In particular, one welcomes the assertion on page 39§ that the real factor of safety in such cases must be based on the elastic limit and not on the tensile strength. This, of course, refers to what one may call "hypo-elastic" uses, as in structures which, in the nature of the case, must not be subjected to stresses great enough to cause important plastic deformation. That this is true of bridges and buildings is evident. For what may be called "hyper-elastic" uses, the tensile strength may possibly be a more useful measure of fitness. A hoisting cable, for instance, need not be unfitted for its use by a degree of permanent stretch which will raise its elastic limit very greatly. Mr. Howe.

Perhaps our view of the whole subject may be clarified by looking at the hyper-elastic part of a tensile stress strain diagram as approximately the locus of the elastic limit. If, at any moment after the yield point has been passed, the stress is released and re-applied, no

* Discussion of the paper by Henry S. Prichard, M. Am. Soc. C. E., continued from April, 1916, *Proceedings*.

† Bedford Hills, N. Y.

‡ "Metallography of Steel and Cast Iron", pp. 526, 625, 626, 634, and 682.

§ *Proceedings*, Am. Soc. C. E., for January, 1916.

Mr. Howe. new permanent set arises until the new stress reaches approximately the maximum hitherto applied, which means that the stress at that point in the diagram is approximately the existing elastic limit of the test piece. The first sentence of this present paragraph is only a generalization from this particular case. In this view, the tensile strength is the maximum elastic limit which the material is capable of developing under other roughly similar conditions, as when a cable is slowly strained beyond its primitive elastic limit up to the point at which it finally breaks.

In this view, the drop of the diagram at the yield point and its later rise represent the algebraic sum of (*A*) the weakening which the test piece is undergoing, (1) because of its progressive loss of section, and (2) from the mobilizing of part of the metal, initially all crystalline; and (*B*) the strengthening which each unit of section is given by the solidification of the momentarily mobilized metal, or, in short, by the plastic deformation itself. At the beginning of the yield, the curve may drop sharply because now the section is decreasing rapidly and mobilization is rapid, whereas the strengthening, which will soon follow this mobilization, has not yet reached considerable proportions. The flat part or jog means that here the strengthening of the material by the deformation is just equalling the loss of strength represented by the simultaneous mobilization of crystalline metal plus the loss of section. This part is probably never truly flat, but a series of waves. The rise of the curve, like the up side of each of these waves, means that now the strengthening caused by the deformation is exceeding the weakening due to the loss of section, and the final drop on passing the so-called tensile strength or maximum load, like the down side of each of the waves in the jog, means the reverse. In this view the rise of the diagram beyond the jog changes from a miracle to an almost prophesiable phenomenon. On this view, why should hypo-elastic service stresses be based on the so-called tensile strength, which is only a certain strength capable of being developed under conditions wholly different from those of service, and wholly unapproachable in service, instead of on the elastic limit, which is the only strength existing in that service?

The writer had hoped that Mr. Prichard, in addition to showing the practical ineffectiveness, for hypo-elastic services, of the elevation of the elastic limit, or, more briefly, the strengthening, by service deformation itself, would have touched on the important question of the effectiveness of such elevation by pro-service deformation, such as cold rolling and cold drawing. One of the important questions before us is as to the limits within which the strengthening caused by pro-service deformation is effective. There is much to suggest that, under indefinitely repeated reversals of stress-sign, any such pro-service strengthening is wholly ineffective, and that it is the primitive elastic limit alone that determines the endurance, that is, the fatigue strength. Indeed, there are well-informed and just writers who imply that this ineffectiveness is established and certain. If this is true, then the measure of strength of axles, shafting, etc., is given, not by the elastic limit as observed in the material as delivered, but by that determined after the removal of all pro-service elevation of the elastic limit by plastic deformation, and hence the reception tests should be made on pieces annealed say at 600° cent. for the purpose of removing the strengthening caused by cold or cool rolling, or any other form of plastic deformation. The question whether this pro-service strengthening is effective or fictitious under indefinite reversals of stress-sign is of an importance which calls for decisive tests. If ineffective under indefinitely repeated reversals, then the question comes up, for bridge engineers and the like: "What are the limits within which this pro-service strengthening is effective, and beyond which it ought to be effaced before making the reception tests, by 600° annealing or its equivalent?" Mr. Howe.

There are a few minor points which may merit attention. Two reasons suggest themselves for considering the use of the term "proportional limit" rather than "elastic limit" for the limit determined directly from the stress-sign diagram. First, "elastic limit" has been used so widely and persistently in the sense of "yield point" that its use may still leave the reader in doubt as to which is meant, whereas there is no such doubt about "proportional limit". Second, that which we know to be the elastic limit is the maximum stress which just fails to cause a permanent set. It is true that every refinement of measurement lowers the elastic limit which we observe by releasing the load and remeasuring the measured length. Hence the ideal elastic limit is that observed with perfect instruments, and hence it can never be actually determined, but only approximated. Nevertheless, its determination is essentially different from that of the proportional limit, which, for like reasons, can only be approximated. If it is true that the proportional limit and the elastic limit coincide—and, however probable this may be, it is not yet known to be a universal law—then it is a purely empirical observation. Might it not be well to use these terms "elastic limit" and "proportional limit" each as indicating the way in which the determination is made? There are those who actually determine the elastic limit by release and remeasurement, and prefer this procedure. Is it not a little arbitrary to deprive the term "elastic limit" of its natural and obvious application to such determinations, and apply it by force to the proportional limit? What is the gain to offset these disadvantages?

Even if rupture through fatigue is always preceded by tearing, does it follow, as suggested on page 72,* that fatigue is always accom-

* *Proceedings*, Am. Soc. C. E., for January, 1916.

Mr. Howe. panied by tears? Why may not a very important degree of true fatigue occur before even sub-microscopic tears form?

What is gained by complicating the notion of slip by introducing rotation, as on page 77?* The conception of Ewing and Rosenhain, as well as that of Beilby and other writers, if the writer understands them aright, is that slip itself is purely vectorial, consisting of translation absolutely without rotation, though it may be accompanied by rotation which in itself leads to a radically distinct mechanism of deformation, *viz.*, twinning.

Later results have thrown very serious doubt on the inference drawn from Howard's experiment (page 85*) that hydraulic pressure does not affect the properties of metals.

Is the conception (page 90*) that during continued flow there is a prolongation of the mobile state of certain individual particles, as easy and probable as the alternative conception that, during such flow, each particle passes with relative rapidity from the crystalline through the mobile to the rigid amorphous state, and that the continuousness of the flow represents the succession of various sets of particles in this progress?

On either view flow is replaced by rupture as soon as the supply of residual crystalline metal is so far depleted that it no longer suffices to generate, under continuing deformation, mobile metal fast enough to heal the cracks which that same deformation is causing in the metal which has passed beyond the mobile into the rigid amorphous state. The conception that the mobile metal is prevented by continued deformation from setting would imply that such continuance would defer greatly this time of depletion, or, in other words, increase the ductility very greatly, which is not true.

Mr. Irwin. A. C. Irwin,† Esq. (by letter).—The author is to be congratulated on having produced a paper of exceptional merit. It should be of great interest to engineers as an enlightened exposition of a convenient theory and a clear statement of certain changes in the properties of wrought iron and structural steel produced by strain. It is hoped that it will stimulate engineers to a more active interest in the influence of the proximate constituents on the physical properties of iron and steel.

It is hoped also that the use of formulas for fatigue in the design of ordinary static structures will be finally discarded, as the theory advanced in this paper, as well as other theories well authenticated by experiments, show that in ordinary static structures, where no reversal of stress occurs, "fatigue" either does not exist, or is of no consequence.

The theory proposed by Mr. Prichard is open to some logical objections, as well as being apparently at variance with certain knowledge

* *Proceedings*, Am. Soc. C. E., for January, 1916.

† Chicago, Ill.

Mr. Irwin.

obtained and well-proven by various investigators. According to this theory, the internal structure of iron and steel is made up of "grains", "particles", or "crystals"—using these terms interchangeably—and an intergranular material which exists as a film on the surface of each grain, and fills the intergranular spaces. The "grains", "particles", or "crystals" possess and retain the property of almost perfect elasticity under either elastic or non-elastic deformation of the piece. The film, or intergranular material, however, becomes a viscous liquid when the piece is strained beyond the elastic limit, but re-solidifies with great rapidity on the release of the straining forces. The groundwork of Mr. Prichard's theory may be found in the first paragraphs on pages 70 and 72, and the second paragraph of page 90 of his paper,* from which the following conclusions may be drawn:

First.—Elastic deformation is effected wholly by deformation of the "grains", "particles", or "crystals".

Second.—Non-elastic deformation or permanent set is effected wholly through plastic flow of the intergranular material, which causes the grains to slide over each other into new positions—the grains themselves undergoing only elastic deformation and regaining in time their original dimensions, shapes, and bulks, on the cessation of the external straining forces.

Third.—Failure of an over-strained piece takes place wholly by failure of the intergranular material, the grains themselves retaining their integrity and their nearly perfect elasticity.

Fourth.—The recovery of a piece from over-strain is dependent on the extent of elastic deformation of the grains. The push or pull exerted by the forces of elastic return of the elastically strained grains on the "viscous liquid" is all that prevents its immediate re-solidification on the release of the external straining forces, and the magnitude of these forces of elastic return is sufficient to prevent complete re-solidification for a considerable time.

It seems that, if the last conclusion is true, the following should also be true, *viz.*, that elastic change of form of the grains of a piece, under the action of external straining forces, exerts a push or pull on the intergranular material of such magnitude as alone to cause a degree of liquefaction; and that, as the grains suffer considerable elastic deformation at stresses near to, but below, the elastic limit of the piece, a certain amount of liquefaction of the intergranular material must occur, even in elastic strain, to accommodate the changed dimensions and forms of the grains. Some period of time would then be required for recovery from elastic strain, just as in non-elastic strain, because, in both cases, there is the retarding effect of the forces of elastic return of the elastically strained grains; and, furthermore, it

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**Proceedings*, Am. Soc. C. E., for January, 1916.

Mr. Irwin. would be expected that the time for recovery from elastic strain would be some considerable portion of the time for recovery from non-elastic strain, the difference in the two cases being merely one of degree in the magnitude of the same kind of strain. The time required for recovery from any considerable over-strain may be hours or days, and we would be led to expect that the time for recovery from elastic strains produced by stresses at nearly the elastic limit would be at least quite appreciable. On the contrary, no appreciable time is required for recovery from elastic strain, and, therefore, we conclude that no liquefaction or flow of intergranular metal takes place. Further, as liquefaction and retardation of solidification are but counterparts of each other effected by exactly the same kind of forces, *viz.*, those of elastic strain and return, and as no time is required for solidification because of these forces under elastic strain, we conclude that no such liquefaction as that described by the author takes place under non-elastic strain.

The second and third conclusions derived from Mr. Prichard's paper, *viz.*, that non-elastic deformation and final failure are respectively dependent wholly on the plastic flow and failure of the intergranular material, and, accordingly, that the grains themselves retain their integrity and nearly perfect elasticity, are at variance with views—held by metallographers—which have been well proven by experiments.

"Under a progressively augmented strain, rupture takes place, not at the crystal boundaries, but through the crystals themselves."*

"Fractures in fact are always trans-crystalline in properly treated steel, an intergranular fracture being clearly pathological, as for instance, in burnt steel."†

"The plastic deformation of all kinds of iron is primarily in their ferrite. The cementite present, whether pearlitic or proeutectoid, may break or bend, but it probably does not yield plastically to any large degree."‡

"The manner in which a metal yields when the strain exceeds the elastic limit is by slips which occur in the cleavage or 'gliding' planes of the individual crystals."§

The micro-structure of wrought iron and steel is essentially crystalline. In wrought iron and low-carbon steel, this crystalline structure is most perfect in the free ferrite crystals which exist in predominant quantity. Free ferrite crystals are true crystals, in that

* "The Crystallization of Iron and Steel", by J. W. Mellor, p. 91.

† "The Metallography of Steel and Cast Iron", by Henry M. Howe, 1916 ed., p. 293.

‡ "The Metallography of Steel and Cast Iron", by Henry M. Howe, 1916 ed.

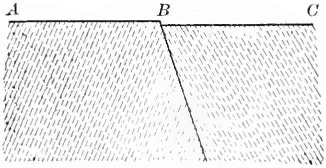
§ Encyclopædia Britannica, 11th ed., Vol. XXV, p. 1018; see, also, "The Crystalline Structure of Metals", by Messrs. Ewing and Rosenhain, *Phil. Trans.* of the Royal Soc., 1900; "The Microscopic Analysis of Metals", by F. Osmond, 1913; W. Rosenhain, *Journal*, Iron and Steel Inst., 1914, No. II, p. 367; and "Introduction to Physical Metallurgy", by W. Rosenhain, 1915.

they are composed of an enormous number of crystalline elements, molecules, or "brickbats", arranged in perfectly regular tactical order. Mr. Irwin.

These elementary molecules or "brickbats" composing a crystal grain have their like axes and faces all parallel in any given crystal. The axes of the "molecular brickbats" in adjoining crystals, however, are not usually parallel, so that each crystal has its own individual orientation.*

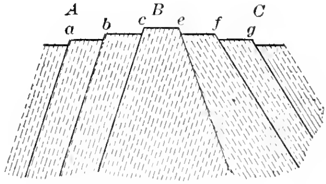
The intra-crystalline slips which are almost wholly responsible for the plastic deformation of wrought iron, low-, and medium-carbon steel, as described and proven by Rosenhain, Ewing, and others, are illustrated by Figs. 8 and 9.

A-B and *B-C*, Fig. 8, represent the polished surfaces of two adjoining ferrite crystals before plastic strain of the piece. The dotted lines represent glide planes of the crystal, that is, the dividing planes between groups of tactically arranged molecular "brickbats". In Fig. 9, at *a*, *b*, *c*, *e*, *f*, and *g*, are steps in the polished surfaces of the



(Before Plastic Strain)

FIG. 8.



(After Plastic Strain)

FIG. 9.

crystals after plastic strain of the piece. These steps are produced by the slip of the molecules on one side of a glide plane over those on the other side of it. The dark lines shown by these breaks in the polished surface of each crystal, under the microscope, have been called "slip bands" and are the "slips" to which the author refers on page 77.† As previously noted, these "slips" are intra-crystalline and not inter-crystalline, as we are led to believe from the paper.

Of so-called impurities that always occur in commercial iron, *viz.*, carbon, silicon, phosphorus, manganese, and sulphur, silicon and phosphorus are retained by the iron in solid solution, and carbon, manganese, and sulphur form compounds with the iron (ferrite) and with themselves, which compounds are rejected to the crystal boundaries or along crystallographic planes while the metal is passing through the critical range; that is, during conversion to the final crystalline structure of ordinary temperatures.

* A popular and lucid explanation of crystallization in a pure metal and the effects of straining Swedish iron, together with an electrical theory of plastic strain and fatigue, is given by James Alfred Ewing in *Memoirs and Proceedings*, Manchester Literary and Philosophical Soc., Vol. 51, 1906.

† *Proceedings*, Am. Soc. C. E., for January, 1916.

Mr. Irwin. The rejected impurities are in the form of definite compounds with iron; the carbon as carbide of iron (Fe_3C, or cementite), the manganese as manganese sulphide (MnS) and manganese carbide (Mn_3C). The cementite combines with ferrite to form pearlite, which appears as a lamellar structure of very thin alternating plates of cementite and ferrite. The ferrite not required to form pearlite is known as "free ferrite", and crystallizes generally in the cubic system.

Steel having less than about 0.85% of carbon is known as hypo-eutectoid, and is composed essentially of pearlite and free ferrite. These constituents vary proportionally with the carbon present. Thus, pure iron is made up of ferrite crystals with no pearlite present. With a very slight carbon content, the ferrite crystals will have interspersed between them small pearlite masses. With increase in carbon, the pearlite increases in proportion until a connected net is formed, the meshes of which are completely filled up with ferrite crystals. With further increase in carbon, the pearlite net occupies more and more space until it becomes the meshes of a ferrite net, and finally the steel is composed entirely of pearlite. Steel composed entirely of pearlite is known as eutectoid steel, and results when the carbon content is just sufficient to form cementite in such quantity as to require just the total ferrite present to form pearlite. The carbon content of eutectoid steel is variously given as from about 0.82 to 1 per cent. If the cementite is in excess of the quantity required to form pearlite, the resulting steel is known as hyper-eutectoid. In the latter case excess cementite is known as "free cementite".

The physical properties of ferrite, pearlite and cementite, according to Sauveur, are as given in Table 6.

TABLE 6.—PHYSICAL PROPERTIES OF FERRITE, PEARLITE, AND CEMENTITE.

Constituents.	Tensile strength, in pounds per square inch.	Elongation, percentage in 2 in.	Hardness.
Ferrite	50 000	40	Soft.
Pearlite	125 000	10	Hard.
Cementite	5 000 (?) *	0+	Very hard.

* It seems very probable that cementite has a considerably higher tensile strength than 5 000 lb. per sq. in., and an appreciable elongation percentage.

In Table 7 is reproduced the author's Table 1, except that computed percentages of ferrite, pearlite, and cementite are substituted for the columns for yield point. It will be noted in this table that the elastic limit increases, in general, with the percentage of pearlite, and indicates clearly the influence of this constituent on the elasticity of the material. It is well known, too, that the total percentage of elongation at ultimate decreases, in general, with increase in the carbon content, that is, with the increase in the percentage of pearlite. This is to be expected from the comparatively low elongation of pearlite given in Table 6. Moreover, the percentage elongation given for pearlite is much less than that obtained from low-carbon or "medium" steels. It is evident, therefore, that, although the intergranular material, that is, pearlite, greatly influences the elastic strength, it is not responsible for the ultimate elongation of such steels, and that we must credit the ferrite with by far the most important role in plastic deformation. Mr. Irwin.

TABLE 7.—TESTS MADE AT WATERTOWN ARSENAL, AND GIVEN IN THE REPORTS FOR THE YEAR 1886, PP. 1635-1653, AND FOR 1887, PP. 802-822.

Marks.	Composition, Percentage of:			Modulus of Elasticity.		Elastic Limit.		Constituents.	
	C.	Mn.	Si.	Compression, in pounds per square inch.	Tension, in pounds per square inch.	Compression, in pounds per square inch.	Tension, in pounds per square inch.	Percentage of free ferrite.	Percentage of pearlite.
833	0.09	0.11	....	30 120 000	30 151 000	30 500	30 000	89.2	10.8
123	0.20	0 45	....	30 303 000	30 151 000	37 000	39 500	76.0	24.0
782	0.31	0.57	....	30 612 000	30 000 000	44 500	46 500	62.8	37.2
795	0.37	0.70	....	31 250 000	30 151 000	47 000	50 000	55.6	44.4
805	0.51	0.58	0.02	30 075 000	30 000 000	57 000	58 000	38.8	61.2
797	0.57	0.93	0.07	30 201 000	30 104 000	55 500	55 000	31.6	68.4
823	0.71	0.58	0.08	31 034 000	30 088 000	55 500	57 000	14.8	85.2
750	0.81	0.56	0.17	30 000 000	29 923 000	74 500	70 000	2.8	97 2
756	0.89	0.57	0.19	30 612 000	29 864 000	76 500	75 000	1.0*	99.0
334	0.97	0.80	0.28	30 822 000	29 817 000	83 000	79 000	2.7*	97.3

* Free cementite.

When wrought iron, or low-carbon or "medium" steel, is strained within its elastic limit, the pearlite takes stress in proportion to its strength to resist elastic deformation, and lends aid to the weaker ferrite crystals. So long as the elastic limit of the pearlite is not passed, there is no slip in the ferrite grains, excepting, perhaps, in isolated grains, the orientation and disposition of which, with respect to the surrounding pearlite and adjacent ferrite grains, presents them in the most unfavorable position to resist the straining forces. When the elastic limit is passed, small slips or cracks occur between or through the plates of the lamellar pearlite, or at the boundaries between ferrite and pearlite, or at any of these places in combination, so that a greater proportion of stress is thrown on the ferrite. Moreover, the support accorded to the ferrite by the pearlite is thus removed, to a degree, and the result is slip along the crystallographic

Mr. Irwin. planes of the ferrite crystals. This slip is accomplished by the disarrangement of molecules along the glide planes affected—the greater the slip the greater the disarrangement and the more molecules affected. Disarranged molecules appear as an amorphous material in the planes of slip, and, under severe over-strain or many reversals, at the intersection of the slip planes with the boundaries of the crystal grains. This amorphous material forms a very thin film—of perhaps molecular thinness—along the slip planes, and when extruded at the grain boundaries may fill cracks in the intergranular material that register with the planes of slip. If the over-strain is slight, the disarranged molecules will rearrange themselves, in something like their former orientation, with those of the crystals from which they were broken; but, in the case of considerable over-strain, their disarrangement is so great that they remain in an amorphous condition. This amorphous metal is hard and quite strong, and binds the parts of the crystal so strongly together at the planes where slip occurred that the planes on which no slip has occurred are planes of weakness in comparison. Thus, the weak portions of the piece have their strength increased and a greater application of stress will be required to produce further plastic deformation than was required in the first instance—the deformation being now effected by slip along planes not thus far affected. This process results in the development or increase in the elastic strength of the piece as a whole.

Under severe over-strain, slips occur, not only along the three principal glide planes of the crystal, but along other planes, so that the polished surface of the crystal becomes checkered with numerous intersecting slip lines. Final fracture of the piece is initiated by the opening up of a minute crack along a slip plane of some crystal which registers with a minute crack or slip in the pearlite. The crack quickly widens and propagates to other crystals through the more or less broken up pearlite, until fracture takes place. If the stresses producing final failure are applied quickly, as by shock or by continuous rapid reversals, "the resulting fracture exhibits the crystal faces upon which slip has taken place as a number of bright facets resembling those produced in a 'brittle' shock fracture, and it is this appearance which has led to the mistaken idea that alternative stresses cause metal to become crystalline."*

The time of recovery from over-strain will depend on the degree of disarrangement of the molecules and the hindrance to their adoption of the most stable arrangement possible under their condition of confinement.

The process of failure by "fatigue" under repeated reversals of stress is explained on the same basis of slip in the crystalline grains. The amount of slip, and hence formation of amorphous metal, is

* "An Introduction to the Study of Physical Metallurgy", by W. Rosenhain, p. 254.

greatly augmented by reversal of the direction of slip before the disarranged molecules can adapt themselves to the new conditions, that is, before the amorphous metal can harden. The slips in the weak crystal are thus continued until a crack is developed which spreads to other crystals. Fracture finally occurs at a unit stress for the piece much below that required for a stress in one direction intermittently applied. In the latter case, the primitive elastic limit arising from slight slips in unfavorably oriented and located crystals is eliminated, and the normal elastic limit developed in the piece. Therefore, the use of fatigue formulas in proportioning the members of static structures under uni-directional stress has no rational basis. Moreover, their use produces a poorly balanced design. If fatigue formulas are recommended for the reason that they allow a margin for impact, the reply is that such use of them relegates to the realm of unscientific guessing a matter about which fairly definite knowledge is available in the various reports of the Sub-Committee on Impact and Secondary Stresses of the American Railway Engineering Association. Mr. Irwin.

In addition to making the provision for dead load relatively too small for long-span bridges, "fatigue" formulas (and others) result in making the provision for live load in certain members relatively too small in short- and medium-span bridges. This becomes apparent when it is desired to load the bridges to their maximum carrying capacity.

In general, the writer believes that a properly balanced proportioning of bridge members is most likely to result from separate consideration of all stress-producing factors and the use of the highest unit stress to which the material may safely be subjected. The assumed loading should then be the heaviest that will ever come on the structure, and the total stress that obtained by taking the sum of dead load, live load, live-load impact, and the secondary stress resulting from the deformation produced by the primary stresses. With this method of design, it will not be necessary to replace bridges because of certain weak members before they are loaded to the maximum carrying capacity of the majority of their parts.

Mr. Molitor. DAVID A. MOLITOR,* M. AM. SOC. C. E. (by letter).—The author, in this paper, brings to the attention of the Profession a valuable collection of data which should serve to strengthen similar arguments and opinions previously advanced by others.

It should also materially assist in relegating to the past, several formulas which have retained a place in specifications for no better reason than a lack of moral courage to cast them out.

One very important matter, also clearly indicated by column tests other than those given in the paper, is the remarkably close agreement

* Toronto, Ont., Canada.

Mr. Molitor. between the ultimate strength and elastic limit, or better, limit of proportionality. Of course, this can only be true for columns of considerable length; for very short columns or cubes, the ultimate strength is practically the same in both tension and compression and, for columns still shorter than the side of a cube, the ultimate compression may be called the flowing strength and is the highest strength attainable. These three classes of failure under compressive stress are explained by combined bending and direct stress for long columns, true direct stress for cubes, and flowing stress for plates.

In tension specimens we observe an elastic limit approximately the same as for compressive stress, though the ultimate strength is about twice as great.

We are naturally forced to the admission that any stress in excess of the elastic limit, whether it is tensile or compressive, will result in some permanent injury to a structure, owing to a permanent deformation due to the excess stress. This may not be true of a piece not forming part of any structure, but we are usually concerned with structures consisting of a multiplicity of pieces in which each piece has a certain duty to perform. Hence, a sufficiently great number of repetitions of stress in excess of the elastic limit must ultimately cause failure, a fact clearly demonstrated by the experiments of Wöhler, Bauschinger, and others.

Therefore, in so far as we are concerned with structures, the elastic limit of the material, both in tension and compression, must also be the limit of permanent usefulness of any given structure, even though the ultimate strength in tension for a single condition of stress, may be double that in compression for any of the component parts.

In the case of the collapse of any bridge, as a result of gradually applied overload to the point of failure, the initial failure will always be in the highest stressed column and not in a tension member, provided the design was based on a uniform factor of safety with respect to the elastic limit of the material used. To avoid this, columns would have to be made almost twice as strong as common practice demands. The Quebec Bridge failure clearly points to this conclusion.

However, a structure designed for unit stresses approaching the elastic limit simultaneously in all its members for a 100% overload, would obviously have a factor of safety of 2 throughout, would be uniformly safe, and would be considered a prudent design. Unfortunately, most bridges have not been designed in this way in the past, and generally have some members in which the unit stress resulting from overload increases at a greater rate than the rate of increase in the load applied. All members, in which the dead-load stress is of opposite sign to that of the maximum live-load stress, belong to this class; likewise all members, the live-load stresses of which are produced by a partial loading of the span. Mr. Molitor.

Various specifications have been written to obviate this difficulty, but, in most cases, these involve the addition of metal to certain members, without any logical system.

The writer has devised a method of design which effectually overcomes the difficulties here mentioned, with the idea of producing structures of uniform strength throughout, for an overload of 100% in the live load, without ever exceeding the elastic limit of the material. As a basis of design, the allowable unit stress in tension is taken as $f = 16\,000$ lb. per sq. in., and, in compression, $f = 16\,000 - 60\frac{l}{r}$ for fixed ends, and $f = 16\,000 - 80\frac{l}{r}$ for one or two hinged ends. This method is described here for the first time.

The stresses in the chord members and end posts are directly proportional to the total loads covering the entire span length, hence to double the live load will increase the unit stresses in these members by a constant percentage, always less than 100% so long as the dead-load stress is greater than zero. However, this same overload will generally increase the unit stresses in the web members in a much greater ratio than for the chords, hence the following specifications:

Members subjected to dead- and live-load stresses of the same character, and in which the maximum live-load stress is produced by the maximum live load covering the whole span, shall be proportioned for the sum of the dead-load, live-load and impact stresses, on the basis of the allowable unit stresses, f, given for tension or compression, as the case may require. This applies generally to chords and end posts. With the correct section thus found and a total stress, $s' =$ (dead load) $+ 2$ (live load) $(1 + I)$, find the unit stress, f', resulting from 100% overload in the live load; and also find the factor, $k = \frac{f'}{f}$ (always less than 2), which represents the ratio of increase in the unit stress, f, due to 100% overload. This factor, k, will necessarily be a constant for all members of this class. The impact, I, will be $\frac{165}{l + 150}$ for railroad bridges.

Members subjected to dead- and live-load stresses of the same or opposite character, and in which the live-load stress is produced by a partial loading of the span, as for web members generally, shall be proportioned for the algebraic sum of the dead- and live-load stresses plus impact, using a unit stress, kf, where f is the allowable unit stress in tension or compression, as the case requires. Where a reversal in live-load stress is possible, the sectional area should be

Mr. Molitor. computed separately for each combination with the dead-load stress, and the larger area will govern the design.

A structure designed in this way will have a minimum factor of safety of 2 on the elastic limit for the assumed live load and will be uniformly safe for an overload of 100%, in the live load. The unit stresses for the overloaded condition will thus approach the elastic limit for short spans wherein the dead-load stresses are small compared with the live-load stresses. The following example will illustrate the method.

Example.—Given, a single-track span of 452 ft., with 16 panels. (Intermediate span of the Memphis Bridge.) Compressive stresses are negative.

Top chord, $U_6\ U_8$

Dead-load stress	=	— 1 200 800 lb.
Live-load stress	=	— 889 500 "
$I = 0.275$......	=	— 244 500 "
Total s.........	=	— 2 334 800 lb.

$$\text{Area required} = \frac{2\ 334\ 800}{15\ 650} = 149.3 \text{ sq. in.}$$

$$f' = \frac{3\ 468\ 800}{149.3} = -\ 23\ 260 \text{ lb.}$$

$$k = \frac{f'}{f} = \frac{23\ 260}{15\ 650} = 1.485.$$

Diagonal, $U_8\ M_7$

Dead-load stress	=	— 20 100 lb.
Live-load stress	=	— 111 900 "
$I = 0.408$.....	=	— 45 700 "
Total s.........	=	— 177 700 lb.

$$\frac{s}{f} = \frac{177\ 700}{10\ 675} = 16.64 \text{ sq. in.}$$

$$f' = k\ f = 1.485 \times 10\ 675 = 15\ 850 \text{ lb.}$$

$$\text{Area required} = \frac{335\ 300}{15\ 850} = 21.15 \text{ sq. in.}$$

$$\frac{335\ 300}{16.64} = 20\ 150 \text{ lb.} = 1.89\ f$$

This shows that, for double the live-load stress, the unit stress in the top chord was increased 1.485 times; and, for the post, $U_8\ M_7$, the same overload would have increased the unit stress 1.89 times on the basis of 16.54 sq. in. of area. The actual area required by the foregoing specification is 21.15 sq. in. This same post also receives a counter stress in tension equal to the compression, but, as the dead-load stress is compressive, the counter stress did not give the maximum gross area. Mr. Molitor.

Returning to the question of fatigue, which is merely a phenomenon of over-stress, and not particularly due to repetition of stress, the writer quotes the following:*

"*Fatigue of the Material.*—Based on the classic experiments of Wöhler (1859-1870) which were continued by Professor J. Bauschinger, a formula was proposed by Launhardt (1873) and later modified by Weyrauch, aiming to apply the principles of the fatigue of material to the design of bridge members.

"Wöhler's law states that for a large number of repeated load applications, rupture of a material is produced under stress which is below the ordinary (static) breaking strength of that material. The conditions under which Wöhler's experiments were made differ so radically from those attending the actual operating conditions of bridges, that it is questionable whether anyone is justified in applying the Launhardt-Weyrauch formulæ to bridge designs.

"Wöhler's load repetitions followed in quick succession and were continued without interruption (several million times) until failure was produced. Bridge members are subjected to a repetition of stress which is always followed by a rather long period of rest, and few structures, even under the heaviest traffic, are retained in service long enough to receive several million applications of the moving load. Also, a well-designed bridge is never calculated for stresses approaching even the elastic limit, while Wöhler bases all his observations on stresses exceeding this limit.

"In addition to these facts, modern experiments made under conditions which correspond quite closely with bridge practice, though limited in extent, point uniformly against the existence of fatigue in bridges.

"The above mentioned Launhardt-Weyrauch formulæ have been extensively used in designing bridge members and are still retained in many specifications. However, this practice does not seem justifiable, especially when allowance is made for impact and secondary stresses generally.

"The fatigue formulæ undoubtedly served a good purpose in the days when so many important factors were neglected, but at present the aim should be to make proper allowance for all the known stress elements and thereby reduce the 'factor of ignorance' to a minimum."

One hundred trains per day would give 3 600 000 load applications in 100 years; and a sample of wrought iron required 10 150 000 repetitions of a load of 35 000 lb. to produce failure.

As material undergoes a permanent set when stressed above the elastic limit, it is quite probable that such an excessive stress, if maintained sufficiently long, will produce failure. The great number

* From "Kinetic Theory of Engineering Structures," published 1910, p. 265.

Mr. Molitor. of repetitions necessary to produce failure is undoubtedly due to the very short duration of each stress application.

Of far greater importance is the uniformity of bridge steel, which in the present state leaves room for much improvement. The writer refers particularly to such defects as piping and segregation, and those who may be interested in this matter are referred to his discussion of the paper by J. A. L. Waddell, M. Am. Soc. C. E., entitled "The Possibilities in Bridge Construction by the Use of High-Alloy Steels."*

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* *Transactions,* Am. Soc. C. E., Vol. LXXVIII, 1915, p. 1.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

THE FLOW OF WATER IN IRRIGATION CHANNELS

Discussion.*

By W. G. Hoyt, Assoc. M. Am. Soc. C. E.

W. G. Hoyt,† Assoc. M. Am. Soc. C. E. (by letter).—Though this discussion deals primarily with the flow of water in natural channels, it has also some bearing on the flow of water in irrigation channels, especially those constructed of earth. Mr. Hoyt.

During a considerable part of the year, the channels of many streams contain a plant growth—both natural and artificial—that tends to retard the velocity of the water, increase the cross-section necessary to carry a given volume of water, and cause some local changes in slope. Apparently, such growth has sufficient effect on the regimen of the stream to change the value of n from 0.016 for earth channels in excellent condition to 0.030 for channels subject to heavy "growths of moss or other aquatic plants."‡

The writer has been unable to find, in any treatise on hydraulics or irrigation, any information as to the character or duration of the plant growth, or its absolute effect on the flow of the water.

Fortunately for the purpose of this discussion, but unfortunately for the purpose of collecting records of stream flow, the United States Geological Survey has maintained gauging stations at points on certain streams in Minnesota and Wisconsin where aquatic plants grow in considerable quantities during the summer, and the results obtained at these stations show the effect of the plant growth on the flow of the rivers. The gauging station on Elk River, near Big Lake, Minn., affords a typical example. Elk River, which drains an area

* Discussion of the paper by George Henry Ellis, Assoc. M. Am. Soc. C. E., continued from April, 1916, *Proceedings*.

† Madison, Wis.

‡ *Proceedings*, Am. Soc. C. E., February, 1916, p. 198.

Mr. Hoyt. lying chiefly in Benton and Sherbourne Counties, rises in T. 38 N., R. 29 W., at approximately 1 150 ft. above sea level, flows south and east, and enters the Mississippi 20 miles up stream from Minneapolis, at an elevation of 858 ft. above sea level. At the gauging station, about 8 miles above the mouth, the drainage area is 615 sq. miles. Records collected from 1911 to 1915 show a mean flow of 200 sec-ft., a maximum of about 5 000 sec-ft., and a minimum of about 50 sec-ft. The flow during the summer varies from 100 to 300 sec-ft.

The effect of aquatic plants appears about June 1st, increases gradually through July and August, and disappears about November 1st. Between the time when the ice leaves the river and June 1st, and between November 1st and the formation of ice, a sufficient number

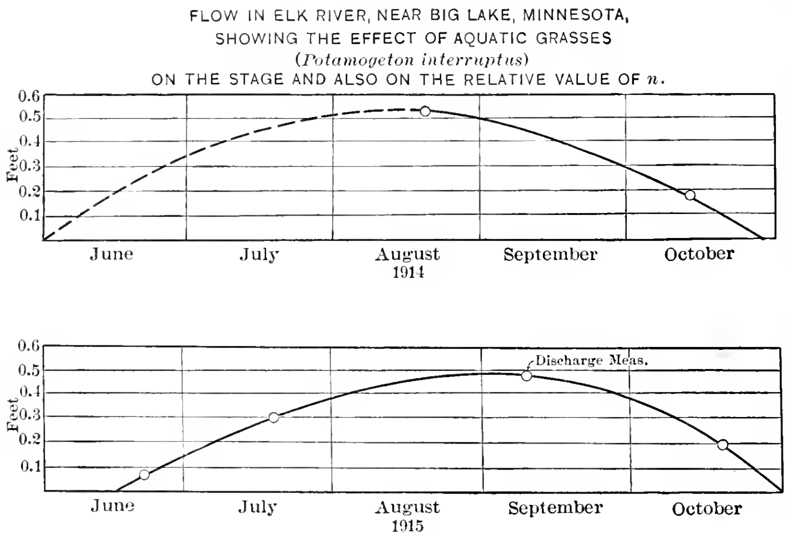

FIG. 10.

of current-meter measurements have been made to determine the relation of flow to stage in the unobstructed channel. If the only changes in the condition of the channel are those caused by aquatic plants, it is possible to measure the effect of such growth on the stage of the river when the flow is uniform. The effect is shown graphically by Fig. 10, which has been prepared by assuming uniform conditions of flow during 1914 and 1915. The curve for 1915 is more complete than that for 1914. It is assumed that there was no back-water due to plant growth on June 1st, 1914, and November 1st. The back-water shown by the discharge measurement on August 20th was +0.53, and that of October 14th was +0.17. In 1915 the maximum effect of back-water was approximately +0.47, as shown by the discharge measurement on September 9th, and back-water from plant growth affected the stage from June 15th to October 31st. As data relating to slope and cross-section are not available, it is not possible to show the absolute effect of this plant growth on n, but it is believed that the curve shows a relative effect on the value of that factor. Mr. Hoyt.

The aquatic plant most common in the streams of Minnesota and Wisconsin is *Potamogeton,* of which there are apparently sixty-five well-known species. That which grows in the Elk River is probably *Potamogeton interruptus.* The popular name is pondweed. According to MacMillan,* and Britton and Brown,† most pondweeds are submerged plants growing in ponds, lakes, and slow streams in many of the northern States and Canada. About twenty species are known in Minnesota, and some forty in Wisconsin. They are rooted in the soil under the water, rather than attached to rock or growing loose in the water. Their stems are branching, and when taken out of the water are limp, owing to poor development of woody tissues. The flowers are commonly collected on spikes, which in the spring are barely thrust above the water in order that the wind may carry the pollen from the stamens to the stigmas. Very closely related to the pondweeds are the Naiads, which may be distinguished by the solitary pistil which forms the fruit.

The growth of aquatic plants depends largely on the temperature, depth, velocity, and chemical contents of the water, the length of growing period, facility for rooting, and other factors that influence plant life. *Potamogeton* is a perennial growth, the plant dying or withering each winter, and the root remaining alive. The more luxuriant growth during 1914 was probably due to higher temperatures in that year, as the mean monthly temperature was higher than in 1915 by 4.3° in June, 8.1° in July, 6.2° in August, 1.8° in September, and 4.0° in October.

Although the aquatic growths are often spoken of as "grasses" or "mosses", few of the plants growing in streams belong to the grass family, and the "moss" said to grow in irrigation channels is undoubtedly a species of algæ.

It is not the object of this discussion to criticize Mr. Ellis' paper, but rather to submit evidence showing the effect of aquatic growth on river regimen—a subject which apparently has received little attention by engineering writers.

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* "Minnesota Plant Life."

† "Flora in Northern States and Canada."

AMERICAN SOCIETY OF CIVIL ENGINEERS

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PAPERS AND DISCUSSIONS

DESIGNING AN EARTH DAM HAVING A GRAVEL FOUNDATION, WITH THE RESULTS OBTAINED IN TESTS ON A MODEL.

Discussion.*

By Messrs. W. G. Bligh, J. C. Oakes, C. E. Grunsky, H. T. Pease, Malcolm Elliott, and Edward Wegmann.

W. G. Bligh,† M. Am. Soc. C. E. (by letter).—This paper is of exceptional interest, as it deals with the first actual experiment made in many years with the object of ascertaining the value of the reduction in pressure or head caused by vertical obstructions such as curtain-walls or diaphragms of sheet-piling projecting below the base of a dam. Mr. Bligh.

Any experiments with models, to be of authoritative value, must be on a reasonably large scale, and, further, the conditions should not deviate from those actually encountered in practice. In the present case, the scale of the model is considered too small, and might well have been 10 ft. to 1 in. However, the experiments in question were undertaken by private parties for a specific purpose, and the results obtained are sufficiently reliable for the aim in view. It is devoutly to be hoped that this good work may be continued, and this much discussed point finally disposed of in a convincing and indisputable manner. With regard to the second suggested condition, the experiment is all that could be wished, the relation between the head of water and the length of base provided in the model, being the

* This discussion (of the paper by James B. Hays, Jun. Am. Soc. C. E., published in March, 1916, *Proceedings*, and presented at meeting of April 19th, 1916) is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† Toronto, Ont., Canada.

Mr. Bligh. same as would be the case in the actual dam when constructed. This condition has not been observed in the paper by J. B. T. Colman, Assoc. M. Am. Soc. C. E., on "The Action of Water Under Dams",* where the disproportion between the head of water and the length of travel provided for the percolating under-current is unreal and, in a measure, must vitiate the authoritative value of the deductions obtained.

In the model dam, the base length was made dependent on actual experimental data obtained by filtration. This determined the net value of base length or travel of the percolating current requisite to neutralize entirely the head of water. It is quite evident that the length thus obtained must in many cases be a maximum value, whereas the minimum safe base length is the real criterion. Supposing the base to be shortened, the neutralization of the whole head would then still take place, but the velocity of the percolating undercurrent would be increased, as well as its ability to wash out and carry away particles of sand or gravel from under the dam and thus threaten piping action, which, in time, would cause undermining. This minimum length of travel suitable to any description of substratum could be obtained by actual experiment to which a factor of safety would necessarily be applied of, say, not less than 1.3. It is possible that, in certain cases, the base length thus deduced would nearly equal the maximum, but in nearly all instances it will be very much less. For example, in the extreme case of a loose boulder river bed, the length requisite to neutralize completely a given head of water by filtration would be altogether impracticable; on the other hand, owing to the weight of the individual particles composing the foundation, a comparatively high velocity in the undercurrent would be admissible with a correspondingly reduced length of base. As far as the writer is aware, no comprehensive experiments have ever been undertaken to solve this matter in a really satisfactory manner.

The so-termed "percolation factors", first introduced some years ago by the writer, were deductions from actual failures of certain large river works, and although they are undoubtedly reliable for beds of pure sand, and have been accepted as such, still further definite experimental data would be most desirable.

This experiment demonstrates that the loss of head due to the vertical diaphragms is proportionally less in the rear than in the fore sheet-piling and that, in neither case, is this neutralization in agreement with the so-termed "creep" theory. The author attributes the great difference in the effectiveness of the two lines of sheet-piling to the much greater depth of fore piling as well as to its location half way down the base of the dam, the assumption being that the obstruction of the deep curtain in the center of the base acts as a throttle valve

* *Transactions*, Am. Soc. C. E., Vol. LXXX, p. 421.

to the percolating subcurrent at a position where the latter is well under way, thus causing a sudden loss of head. This view the writer deems to be correct, but applicable only to the quite abnormal conditions present in the experimental model. The depths given to the sheet-piling are far in excess of actual practice. That of the central line reaches to 125 ft. below the base of the dam, that is, to half the depth of the porous stratum; half the waterway is thus cut off, which must cause congestion. It is quite possible that this throttle-valve action may exercise a retroactive effect on the rear diaphragm, reducing its efficiency. However this may be, it is evident that the abnormal conditions existing in the model render the results obtained from the experiment of small practical value, and that the actual neutralizing effect of vertical curtain-walls remains still to be decided by further experiments made under normal conditions. Mr. Bligh.

Mr. Colman, in the interesting discussion on his valuable paper previously mentioned, states that, in his opinion, sheet-piling is of no value in the reduction of head because it is not absolutely water-tight. This view is also held by irrigation engineers in India. In that country curtain-walls are made of oblong masonry under-sunk blocks, the narrow spaces between which are closed as well as practicable with concrete. Reliance, however, is not placed on these massive curtains with regard to their capability in the neutralization of uplift. In Egypt, cast-iron piles were used in the Assiut Barrage, and each joint was provided with a hollow space which was filled with cement grout. It is believed, however, that the vertical length was omitted from consideration, owing to the lack of reliable data regarding their action. From these remarks, it will be evident that experimental data of a positive and exhaustive nature regarding this important subject would be a great boon to the Profession all over the world. Until such data are obtainable, it is thought that the theory of "creep", which even Philip à M. Parker,* M. Am. Soc. C. E., has termed "fascinating", should hold good as a fairly accurate and safe guide in design.

Some new developments have recently been made by the writer and published in a small work entitled, "Dams and Weirs", a copy of which has been presented to the Library of the Society.

In this the term "piezometric line" is used for the stepped line which forms the upper boundary of the area of uplift, thus distinguishing it from the hydraulic gradient, which latter is the ratio, $H:L$, L denoting the total length of travel, or creep, vertical as well as horizontal. Whatever value is assigned to vertical obstruction, it is clear that wherever it occurs a step down must result in the piezometric line and, further, as will now be shown, the latter will not necessarily be always parallel to the hydraulic gradient. Where there is no vertical curtain and no part of the superstructure is porous, the hydraulic

* "The Control of Water."

Mr. Bligh. gradient and piezometric lines will naturally coincide. A further development consists in the introduction of a filter bed of porous material, or the insertion of holes in the solid impervious floor or apron, which have the effect of stopping the uplift behind it by allowing the free exit of water. If solid material is prevented from passing out with the escaping water, all deleterious piping action is nullified; consequently, this porous length can be considered as effective as part of the line of travel of the percolating undercurrent. Thus, the direction of the piezometric line will be still further divorced from the sloping line, $\frac{H}{L}$, termed the hydraulic gradient. The introduction of a filter bed in the fore apron of the Hindia Barrage on the Euphrates was the first instance of this kind on a large scale. Another point of importance which may well be mentioned is the formation of a rear apron, impervious to water, behind a high dam by the promotion of silt deposit by the river itself. This process can be facilitated by constructing the dam in stages, thus allowing time for the gradual deposit during several freshets. Many dams owe their safety to this complaisant action of natural forces, which otherwise, due to insufficient provision of enforced travel of the percolating undercurrent, would have failed. One further matter remains to be mentioned while there is opportunity for bringing it to notice: What is the effect, if any, of the imposition of weight on a porous foundation, subject to a head of water, in preventing or delaying its disintegration by piping?

The writer has checked the estimation of the loss of head due to vertical obstructions, according to the "creep" theory, and the results show the author's statements to be erroneous.

In Fig. 8, the length of travel is: horizontal, 745 ft., vertical $(2 \times 65 + 2 \times 85) = 300$ ft. The total value of L, then, is $745 + 300 = 1\,045$ ft. The hydraulic gradient will then be 1 in 10.45. The neutralization of head effected in the rear diaphragm would then be $\frac{2 \times 65}{10.45} = 12.4$ ft.: and that in the fore piling will be $\frac{2 \times 85}{10.45} = 16.2$ ft., as compared with the actual results, 5 and 21 ft., respectively, the discrepancy in the totals being only 2 ft. With regard to Fig. 9, the vertical component is $2 \times 125 = 250$ ft.; adding this to the horizontal, which is the same as before, that is, 745 ft., $L = 995$ ft., say, 1 000 ft., and the hydraulic gradient is 1 in 10. The loss of head due to the vertical diaphragm will then be $\frac{2 \times 125}{10} = 25$ ft. In Fig. 11, the loss of head appears to be about 20 ft. If the piezometric line, due to the theory of creep, were plotted over the experimental one, the differences would be apparent to the eye. This places the theory in a much better position than was previously apparent, and also somewhat discounts the special pleading in its favor made under a partial misapprehension of the facts. However, the experiment being made under abnormal conditions, the results cannot be accepted as convincing. Mr. Bligh.

J. C. OAKES,* M. AM. SOC. C. E. (by letter).—The application of the term "hardpan" to an uncemented material is unfortunate, as the meaning of the word in engineering literature is limited to materials hard to excavate, and more or less cemented by clay, carbonate of lime, oxide of iron, or other binding material. Mr. Oakes.

In the last paragraph of "General Conditions" the stratum of so-called hardpan is referred to as "the impervious stratum." Later, in the experiments to determine the hydraulic gradient of the combined material, it is proved that this material is not impervious, but that it is readily saturated; for the porosity of the combined material is determined by that of the finer material, and, referring to the experiment to determine the gradient of the combined material, the author states:

"In the morning of the second day, fully 80% of the water was still on the surface, and at the end of 47 hours both tubes were filled with water, although the valve at the base had been closed for the entire period."

It is apparent, therefore, that even though the valve at the bottom remained closed, the water drove out the air and fully saturated the material in the tank, as there existed no difference in head in the two tubes at the end of the test period.

The author states that it was found impossible to determine the exact hydraulic gradient of this combined material, because in another test "no water appeared in either of the tubes shortly after the valve was opened." It is evident that a sufficient length of time was not allowed to elapse, else the water would have appeared in the tubes, as proved by the saturation of this material just mentioned. He then assumes that the hydraulic gradient of the combined material "was not greater than 1:1, although it was evidently much steeper."

The writer supposes the author to mean that the slope of the gradient was not less than 1:1, although the tests apparently proved nothing. The slope of the hydraulic gradient in earthen dams is not generally as steep as 1:1, and in fact is seldom steeper than 35:100. It would seem, therefore, that careful and thorough tests should have been made before assuming 1:1 as the proper slope of the gradient for the material in question.

Furthermore, the assumption is made that, by using the combined materials in the up-stream section to secure water-tightness, and avoid

* Major, Corps of Engrs., U. S. A., Louisville, Ky.

Mr. Oakes. transmission of water pressure through that section in any great amount, the hydraulic gradient can be made to begin at or near the up-stream toe of the dam. This is a dangerous assumption, as the material will become saturated, and some seepage will take place. Even if the fine material had been found, experimentally, to be practically impervious, it was not safe to assume that the coarse and fine materials could be mixed on a large scale in such manner that there would be, throughout the whole length of the dam, no points where the mixture would be imperfect, and where water might not seep through the combined material with greater or less facility.

Those who have had experience with filter beds, or have studied their action, know that care must be taken in placing the filter bed materials so that a uniform density will result. Whenever variation occurs, the water readily finds the paths of least resistance, and soon forms small channels through which it escapes. These channels gradually become larger, until the efficiency of the filter is destroyed. Lack of uniformity of the mixture of the materials under discussion will undoubtedly cause similar action, and, with material as fine as that described, a small quantity of seepage may cause piping, or the carrying away of the material, and the destruction of a portion of the up-stream section of the dam. Again, in Table 1, showing mechanical and chemical analyses, it is stated that 52% of the fine material is insoluble. If then, 48% of this earth is soluble, seepage through it may be assisted very materially by the dissolving of the soluble parts.

With reference to the upper line of sheeting used under the first model dam, the author states: "* * * the loss of head is very small and not in proportion to the length of the sheet-piling." He does not explain why this upper row of sheeting did not accomplish as much in proportion to its length as the lower row, but, relying on what seems to be insufficient data obtained from a very small model, he abandons the upper row of piles and evolves a theory, which he claims explains the results obtained, but which, the writer thinks, does not explain those results satisfactorily. This theory is:

> "* * * the sheet-piling cut-off was greatly similar in its effect to a partly closed valve, wherein the water is retarded and shows a higher pressure head just above the cut-off and a lower one just below."

He states that this theory wholly explains the ineffectiveness of the upper row of sheet-piling as a cut-off, but the writer does not see why, if the theory is correct, the upper sheeting should not also have acted as a partly closed valve. In other words, why does not the theory apply to one line of sheeting as well as to the other? It is a generally accepted principle of design that, where the apron is water-tight, the row of sheeting to be most effective must be at the up-stream edge.

If the up-stream section of the dam, composed of the mixed materials, had been impervious, and the sheeting water-tight, it seems to the writer that the greatest effect, in proportion to length, would have been obtained by the upper row of sheeting. The author appears to recognize this faintly, for, in the last paragraph on page 340,* he states: Mr. Oakes.

"In any dam, the correct place for a cut-off wall, under conditions such as these, namely, a pervious foundation, is at, or near the up-stream toe."

This statement is certainly correct when the dam is impervious, but it is not correct in case of a pervious dam or apron. It seems to the writer that the inefficiency of the upper row of sheeting can be readily explained, either by its lack of water-tightness, or by seepage through the material of the dam, between the pool and some point or points of the foundation down stream from the line of sheeting. Owing to the short period of time during which the experiment was carried on, the material above the second line of sheeting, being much thicker, did not become thoroughly saturated, seepage did not proceed directly from the pool through the material of the dam to a point down stream from the second row of piling, and consequently this row of piling did accomplish what was to be expected of it.

Although nothing is said about the length of time to which the model was subjected to the various heads of water, it is noted that, on each of the days that the work was carried on, from four to eight experiments were made. In one case five experiments were made in the afternoon, so that it is very evident that a very short period of time was allowed for each experiment. With the material as fine as that described, complete saturation near the core-wall could not have been expected in such short time, but if, in each experiment, the head had been maintaned for a number of days, complete saturation would have taken place, and it would then have been found that the lower line of sheeting was also inefficient.

Nothing is stated in the paper as to the percentage of voids in the coarser material, but the impression is given that water passed through this material very freely. If, then, after a time, the material in the upper section of the dam becomes thoroughly saturated, the writer does not see what is to prevent the carrying away of the fine material of the dam section through the coarser material of the foundation, thereby causing ultimate failure of the dam. He can see no advantage whatever in placing the line of sheeting as shown in Fig. 9. If the material forming the upper section of the dam is impervious, then the line of sheeting should be near the up-stream edge. If the material is not impervious, then it should be under the core-wall and connected

* *Proceedings*, Am. Soc. C. E., for March, 1916.

Mr. Oakes. therewith to form an impervious sheeting from crest of dam to foot of piles.

Fig. 8 indicates that the proposed dam is to withstand a depth of water of 100 ft., and Fig. 9 shows the design with a base approximately 700 ft. wide. For 100 ft. of this width the dam section is from 10 to 15 ft. thick. As the core-wall and sheet-piling do not necessarily increase the line of percolation, the percolation factor, or ratio of length of line of percolation to head, is approximately 7, which is much too small, if the writer understands the nature of the materials of foundation and dam section. Furthermore, it may be possible for seepage to take place along lines at 45° with the vertical and meeting at the foot of the core-wall, in which case this factor becomes about $2\frac{1}{4}$. This possibility is increased because the core-wall will tend to concentrate the seepage at its foot, and such seepage will escape under the wall and upward through the down-stream section, probably at an angle of approximately 45 degrees.

According to the best authorities, these factors are too low. Among these authorities may be cited Mr. W. G. Bligh, whose experience and theories are dismissed by the author with the statement:

"This theory gives structures of ample dimensions, as has been shown by practice, but was found to be incorrect, after due experimenting, as will be noted later."

If the author means that the experiments that he describes in this paper prove the falsity of Mr. Bligh's theory, the writer must disagree with him, as, in his opinion, the model was too small, the experiments too few, and too little time was devoted to each experiment to warrant any such broad statement. It seems to the writer that erroneous conclusions, or at least unwarranted conclusions, were drawn by the author. It seems very doubtful whether results obtained with such a small model may be considered to hold for heads 120 times as great as those used in the experiments. In writing about the failure of a dam on sand foundations, and giving his opinion on the values of required percolation factors, Mr. Bligh has sounded a warning which exactly covers this case, as follows:

"The proper value of this factor is found, not by artificial experiments on a small scale, but by undisputable statistics which bear on the capacity of the various pervious materials which may compose a river bed to resist the undermining influence of the pressure of the water upheld."

A remarkable statement occurs on page 333,* as follows:

"The long up-stream slope was given in order to allow the downward pressure of the water over the up-stream section to have a balancing effect on the upward pressure beneath the dam, as blow-outs would be improbable in this portion of the dam."

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* *Proceedings*, Am. Soc. C. E., for March, 1916.

If the writer understands this sentence correctly, the author seems to feel that, although improbable, blow-outs may occur in the bottom of the reservoir, and he extends the dam up stream to prevent this by providing something for the down-stream pressure of the water to act on. Mr. Oakes.

Although the author, under "Conclusions", has mentioned the principal causes of failure of earthen dams, he makes a number of statements in the last two paragraphs that do not seem to follow necessarily from the experiments described in this paper. Although possibly true, he has certainly not proved that:

"Where the sand or gravel foundation is of very great depth, a short cut-off would not be as efficient as in a shallower foundation, * * *."

Nor has he proved by his design that:

"* * * where models are constructed, results can be obtained which enable the engineer to make correct designs better than by any other method of study."

It appears to the writer that the use of a very small model, and the lack of certain precautions, such as allowing sufficient time in each experiment for the material to be thoroughly saturated, and the assumption that the material is impervious, or practically so, where it is very evidently not so, has led the author to arrive at erroneous conclusions, and to design a dam, which, if constructed as designed, is likely to fail.

The writer has had occasion to be deeply interested in the subject of dams on sand foundations, and has found no example of a dam on a pervious foundation constructed with a cross-section approaching in boldness that designed by the author. It will be very interesting, indeed, to know whether the dam has been constructed as designed, and, if so, to learn at a later date how it fulfills its purpose.

There is a statement at the end of the paper to which the writer is willing to subscribe in its entirety, as follows:

"Each design is a problem in itself, and the experiments described herein should not be misinterpreted, or applied too broadly."

C. E. Grunsky,* M. Am. Soc. C. E. (by letter).—The question of the effect of water-tight sheet-piling which does not extend entirely through a layer of pervious material, on the hydraulic gradient in that layer, is one of vital importance in many cases where either a dam must be built on a pervious foundation or not built at all. Every contribution toward the solution of this problem should be welcomed by the Profession. The writer suggests one which should be tried out: Mr. Grunsky.

Let D represent the depth of the gravel bed, in feet.

Let d represent the depth of the sheet-piling, in feet.

* San Francisco, Cal.

Mr. Grunsky.

Let s represent the fall, in unity, of the hydraulic grade line for those portions of the gravel bed not affected by the sheet-piling. This is the gradient that will cause a flow in the gravel equal in quantity to the leakage under the dam.

Let S represent the fall in unity required to create the velocity with which the water flows under the sheeting through a section of gravel from B to C, Fig. 12, being a layer with a thickness of $D - d$ ft. in which the water is assumed to flow horizontally.

Let h represent the reduction of hydrostatic pressure due to the sheet-piling, expressed in feet.

The velocity of the water in the gravel is proportional to the hydraulic gradient. Therefore,

$$S = \frac{D}{D - d} s \qquad (1)$$

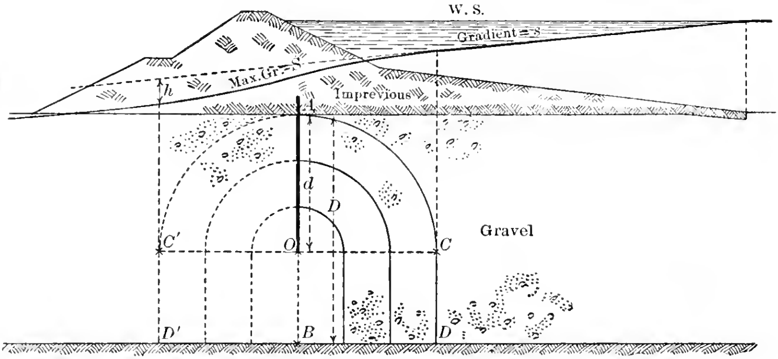

FIG. 12.

The velocity at which water moves through the gravel toward the gravel-filled space, O-B, under the sheet-piling, Fig. 12, decreases with the distance from O-B. Uniformity of velocity at uniform distance from O-B may be assumed. Up stream from the sheet-piling, therefore, the hydraulic gradient should be practically constant at each point of each of the full concentric lines shown in the diagram, and there should be a gradual increase of the gradient from s at the outermost line passing through A, C, and D, to the gradient, S, at all points on the line, O-B. Down stream from the sheet-piling, on the other hand, there should be a gradual decrease of the hydraulic gradient from S at the line, O-B, to s at the outermost of the concentric lines passing through A, C', and D'.

The change in the gradient from s to S, up stream from the line of sheeting, and from S to s, down stream from the same line, is practically proportional to the distance from O-B, because the increase of the area of the gravel through which the water must pass is proportional or nearly so to this distance, and velocity and therefore velocity head in a gravel bed are inversely proportional to cross-sectional areas. Mr. Grunsky.

It follows that the total fall of the hydraulic grade line throughout the distance, C-C', will be

$$\frac{S + s}{2} \times (C\text{-}C').$$

But C-$C' = 2\ (A$-$O) = 2\ d$.

The total fall of the hydraulic grade line in the distance, C-C' = D-D', is, therefore,

$$\frac{S + s}{2}\ (2\ d), \text{ or } d\ \left(\frac{S + s}{2}\right).$$

The fall of the grade line in the same distance, if there were no sheeting, would be $2\ d\ s$.

Consequently:

$$h = d\ (S + s) - 2\ d\ s \qquad (2)$$

$$h = d\ (S - s) \qquad (3)$$

Substituting the value of S from Equation (1),

$$h = d\ \left(\frac{D}{D - d}\ S - s\right) \qquad (4)$$

$$h = \frac{d^2\ s}{D - d} \qquad (5)$$

or,

$$h = \frac{d\ s}{\frac{D}{d} - 1} \qquad (6)$$

When there is no sheeting, $d = 0$ and $h = 0$. When the sheeting extends to bed-rock, then $s = 0$, $d = D$, and h is indeterminate; the flow is completely checked. This also appears from Equation (1), which makes $S = \infty$. The fall in unity at the sheeting is infinity, and the hydraulic gradient comes to a full stop at the line of the sheeting.

Equation (5), applied to the F. C. Horn model, for the particular case when $s = 1:9$, indicates the following for 85-ft. sheeting:

For $D = 240$ ft.
and $d = 85$
and $s = 1:9$

$$h = \frac{85 \times 85}{155} \times \frac{1}{9} = 5.2 \text{ ft.}$$

For 40-ft. sheeting $d = 40$,

and

$$h = \frac{40 \times 40}{200} \times \frac{1}{9} = 0.9 \text{ ft.}$$

For 125-ft. sheeting, the loss of head would be 15 ft.

Mr. Grunsky. These results, it is believed, are fairly dependable. The hypothesis on which they are based is certainly more reasonable than the "creep theory" for which the writer has found no theoretical justification.

It will be noted that the examples here given apply only to the particular cases in which $s = 1:9$, that is, $s = 0.11$. To make comparisons with the experimental results obtained with the model, the first determination should be of the value of s, which will vary for each length of sheeting. The effect of the sheeting expressed by the total drop of the gradient is proportional to s, which is a variable.

The slope of the hydraulic gradient, or value of s, to be used in the equation for h can be ascertained for a model from the volume of flow through the gravel, by making experiments with varying quantities of water, and a corresponding variation of head, before the sheeting is placed in position. For this experiment, however, the gravel should be covered with an impervious material, so that the entire discharge must pass through the gravel. After the sheeting has been placed and the flow of water under it has been ascertained,

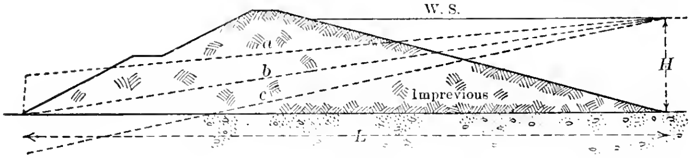

FIG. 13.

this volume will determine, from the results of the preceding experiments, the proper value of s.

There is now to be considered the problem of determining the effect of sheet-piling when the value of s which will obtain after the sheet-piling is in place is not known.

Without any sheeting under a dam of impervious material the hydraulic grade line may have any of the positions, *a*, *b*, or *c*, Fig. 13. When in the position indicated by the line, *a*, the outfall of the water into a channel or other receiver below the dam takes place with a more or less abrupt release of pressure, the dam is in danger. When the hydraulic grade line is in the position, *c*, the flow in the gravel under the dam is so small that water will not appear at the down-stream toe of the dam. When in the position, *b*, all water appearing at the down-stream toe will be under no pressure at the ground's surface, and the water passing under the dam ceases to be a menace.

Let it be assumed that, in the case of the finished structure, which has the benefit of sheet-piling, the hydraulic grade line passes through the down-stream toe, so that the average gradient of the line is $H \div L$. For this particular case, the effect of the sheet-piling can be estimated as follows:

The average gradient throughout a distance of about d feet on either side of the sheeting, as already shown, will be $\frac{S + s}{2}$. Mr. Grunsky.

The value of H will be

$$H = (L - 2\,d)\,s + h \quad \text{.....................} (7)$$

$$H = (L - 2\,d)\,s + \frac{d^2\,s}{D - d} \quad \text{.................} (8)$$

from which

$$s = \frac{H}{L - 2\,d + \dfrac{d^2}{D - d}} \quad \text{...................} (9)$$

$$s = \frac{H\,(D - d)}{L\,(D - d) - d\,(2\,D - 3\,d)} \quad \text{..............} (10)$$

This value of s substituted in Equation (5) will make

$$h = \frac{d^2}{D - d} \times \frac{H\,(D - d)}{L\,(D - d) - d\,(2\,D - 3\,d)} \quad \text{.........} (11)$$

$$h = \frac{d^2\,H}{L\,(D - d) - d\,(2\,D - 3\,d)} \quad \text{.............} (12)$$

This expression for h represents the effect of the sheet-piling when the hydraulic grade line has been brought into the position, *b*, Fig. 13. In the case of earth dams, it will represent the benefit, expressed in head, which may be expected from the sheet-piling under a dam at the safety margin, and therefore the maximum benefit that may be hoped for from the use of sheeting.

The experiments made with the model are not described in the paper so that they enable one to test the equation by the tabulated experimental results. The low heads recorded for the points, H to K, indicate that the water was allowed to flow out of the drain cock. This would cause the gravel bed to act as a filter, and would produce a condition at variance with that which prevails at the dam site, where a free escape of water at, but not below, the level of the stream bed may be assumed. It is possible that the readings on the upper line of tubes and on the lower were not simultaneous, but, if this is the case, this should have been explained in the paper.

H. T. Pease,* Assoc. M. Am. Soc. C. E. (by letter).—This paper is an interesting example of the method expressed by the phrase *reductio ad absurdum*. It shows how far a line of reasoning may be carried beyond a logical limit. Mr. Pease.

No engineer would think of designing a bridge 100 ft. long using a test of a bridge 10 in. long as a basis for the design; especially would

* Deer Park, Wash.

Mr. Pease. he consider the proceeding irrational if the conditions under which the model was tested were different from those actually to be met by the design. Mr. Hays' procedure is analogous to such a case. He has built a very large edifice on a very narrow base, a pyramid standing on its apex. Designing a dam 100 ft. high on the result of the tests of a model 10 in. high is a good deal like designing an ocean liner on the lines of a canoe.

The author's design would undoubtedly prove safe for a dam several feet in height, but that it would prove safe for more than 100 ft. of height is improbable; certainly, he does not prove his case. In a dam 10 in. high the effects of capillarity and viscosity of the water would be largely felt. In fact, they would undoubtedly comprise a large percentage of the total forces acting in this case. Such, however, would not be the case with the 100-ft. dam. These forces here would be negligible.

The final design shown in Fig. 9 indicates a slope of 2:1 on the up-stream face and a slope of $1\frac{1}{2}:1$ on the down-stream face to a depth of 60 ft. Considering the nature of the material, as it is described in the paper, in fact, considering almost any material of which an earth dam might be constructed, this should be regarded as an unsafe section for a dam of this height. A slope at least lighter than $1\frac{1}{2}:1$ should be used for the down-stream face.

The core-wall shown reaching to the top of the dam, in fact, the core-wall in any earth dam, is in most cases a "delusion and a snare". If the material of the up-stream portion is tight enough to hold water, the core-wall is unnecessary; whereas, if it is not tight enough to hold water, the up-stream portion serves no purpose whatever, except as a support for the core-wall when the dam is empty. Moreover, in such a case the pressure of the entire head, supplemented in many instances by an added weight of earth in a semi-fluid state, is brought to bear on the section at the core-wall. To say the least, such a stress would be hard on a thin wall such as is shown in the diagram, because the material supporting it is not rigid.

The up-stream toe would seem to be drawn out to too thin a section. If the material composing it is at all pervious, what is to prevent the finer particles from being carried down into the coarse substratum until this toe becomes as pervious as the ground beneath?

The author states that he has proved the "line of creep" theory incorrect, "after due experimenting". His experiments consist of the test of a model constructed on a very small scale, but of the exact proportions of the actual dam. Every detail but one is thus proportioned; while he was at it he should have reduced the sizes of the grains of the material of which the model was composed to the same scale, *i. e.,* 1: 120. A length of 24 in. of the natural sand and gravel placed under the model represents the 240 ft. of the same material which will be found at the dam site, and in this sheet-piling is placed reaching to within 11½ in. of the floor of the water-tight box in which the model is built. This is to represent piling which will be driven to a depth of 125 ft. below the base of the dam or within a distance of 115 ft. of an assumed rock surface below. That the actual subsurface conditions are thus duplicated in the model is hard to believe. Mr. Pease.

After making some tests for loss of head, the author concludes that the sheet-piling reaching to within 11½ in. of the floor of the box acts as a partly closed valve. There would appear to be an element of truth in his contention—in this case.

The conclusions to be drawn from the paper are:

That the author has shown a commendable enthusiasm and an attention to detail often lacking in such an investigation, but that he has over-estimated the usefulness of the data collected;

That the test conditions do not duplicate the actual conditions to be encountered; and

That the safety of his design is open to suspicion.

Malcolm Elliott,* Assoc. M. Am. Soc. C. E. (by letter).—The author of this interesting paper deserves credit and the thanks of engineers for efforts to throw light on a subject about which little is known, and for making his results and conclusions available to others. In commenting on this series of experiments, the writer wishes to disclaim any intention of merely picking flaws. What appear to be inconsistencies and errors may be due to misunderstandings which should be cleared up by other discussions. Mr. Elliott.

The problem of determining the upward pressure on the base of a dam built on a pervious foundation may be likened to that of determining the lateral pressure of earth on the back of a retaining wall. No general theory of earth pressures will take care of all possible conditions as to cohesion and friction; neither will any general formula represent truly all possible degrees of porosity and permeability in the case of upward pressure on a dam. Nevertheless, for earth pressures, we are content to go on using the Rankine formula, well knowing that it does not accurately represent the true pressures, but using it because it gives practical values sufficiently near the truth for safety in design, when a reasonable margin of safety is provided. In like manner, the so-called "line of creep" theory may not accurately determine the upward pressures at the base of a dam, but it can be depended on as a generally safe rule for design.

The author recognizes that his results are not generally applicable; in his closing words he says that each design is a problem in itself, and

* Louisville, Ky.

Mr. Elliott.

that the experiments should not be applied too broadly. He might have added that his results could be used only for the dam which he was designing, and even then with extreme caution and proper allowances because of the small scale on which the experiments were made.

In using a model for any kind of a demonstration, it is desirable, of course, to reproduce, as faithfully as possible, the actual structure for which the strength or behavior is to be determined. This ideal cannot be attained in constructing models of dams on such a small scale as that used by the author.

In his model, the dam and sheet-piles are very much reduced in scale, though the soil particles are of the same size as those used in the full-scale dam, and the water is of the same degree of fluidity. The interstices in the sand, where it is in contact with the sheet-piles, are much larger, in proportion to the length of the piles, than they are in the actual dam. If the soil were reduced to the same scale as the dam and sheet-piles used in this series of experiments, it would be an impalpable powder; or, looking at it in another way, if the soil particles used in the model were enlarged so as to have the same relation in size to the actual dam as they have to the model dam, the underlying material (Curve *A*, Plate IV) would be a mass of stones and boulders, 90% of which would be composed of pieces more than 2 in. in diameter, 80% would be stones more than 12 in. in diameter, and the largest "particles" would be boulders 10 ft. in diameter.

The tendency of the water to "creep" along the surface of the sheet-piles would possibly be greater in the actual dam than in the model, because of this difference in the size of the particles and their interstices when compared with the length of the sheet-piling. This seems to be substantiated by the greater proportionate loss of head at the second or longer row of sheet-piling. Here the measured loss of head for a 100-ft. head was from 19 to 21 ft., and the computed loss of head, according to the "line of creep" theory, with the hydraulic gradient of 1:9, would be *18.9 ft. From the very small loss of head at the first or shorter row of sheet-piling, the author deduces that this piling is of little value; and, in his second model, he eliminates it and adds to the length of the second row. The writer believes that if the author had used a model on a larger scale, or if he had increased the length of the up-stream row of piles in the model which he used, the loss of head due to the piles would have been more nearly in accord with that computed with the "line of creep" theory.

The small loss of head at the up-stream piles might also be explained in part by leakage through the apron on the up-stream slope of the dam. If, as is claimed by the author, this covering were impermeable, the logical place for the single row of sheet-piling would be

* Not 9.4 ft., as stated by the author. This is the loss of head on only one side of the sheet-piling.

in the up-stream trench, instead of the down-stream trench, and the concrete core wall would be superfluous. Even a small leakage through this up-stream apron over the top of the upper row of piling would raise the hydraulic grade line down stream from the piles, thus apparently reducing the loss of head due to the piles. In his paragraph immediately preceding his conclusions, the author recognizes the possibility of leakage over the tops of the piles, when he says the piling was located "sufficiently far back to prevent any water from seeping through the dam to the down-stream side of the piling", yet he does not attribute to this possibility the apparent failure of the "line of creep" theory at the upper row of piles. Mr. Elliott.

One of the striking characteristics of the author's experiments is the apparently large loss of head where the water enters the sand. Thus, if the curve for Experiment 9, Fig. 10 (*a*), is extended to the toe of the dam on the same slope as between Tubes *B* and *C*, it appears that there will be a loss of head at entry of about 5½ in., out of a total head of 10 in. In giving his results in feet (the actual readings multiplied by 120), the author would apparently have us believe that the values he gives would approximate those to be expected with the full-scale dam, and that the loss of head at entry would be about 55 ft., out of a total head of 100 ft. If this were true we would have a surprising departure from hitherto accepted theories, which have been to the effect that the entry head, though appreciable, is not generally a large proportion of the total head.

It is seen immediately, however, that accepted theories as to the amount of the entry head are not destroyed by the results of these experiments. The loss of head at entry is more nearly an absolute than a relative quantity; it does not vary with the total head, but with the velocity head. The velocity head with the actual dam will certainly not be 120 times that with the model dam; therefore the loss at entry will be relatively much smaller than with the model dam, leaving a much larger proportion of the total head to be overcome by friction, and thereby changing materially the slope of the hydraulic grade line.

Yet, if we should accept these experiments as conclusive, even with the limited applicability which the author claims for them, they would indicate a loss of head at entry, in the actual dam, of 55 ft., though, as a fact, it will be nearer 5½ in.

This difference between the model and the actual conditions is one of the fundamental reasons why the solution of this problem should not be attempted on such a small scale. The model should be of such size, compared with the actual structure, as to make negligible the error introduced by assuming that the loss of head at entry is proportional to the total head.

Mr. Elliott. The departure of the author's results from those obtained by the "line of creep" rule may be explained largely by the relatively great loss of head at entry which is due to the small scale on which the experiments were made. With experiments on a larger scale, or under actual conditions, the loss at entry is insignificant, compared with the total head, so small, in fact, that it is entirely neglected in the "line of creep" theory as ordinarily applied.

The writer confesses not being able to understand the author's reference to the "hydraulic gradient of the underlying material" which he assumes to be 1 : 9 throughout. Apparently, he determined this by his preliminary experiments with the circular tank, and then for his trial design assumed that a certain down-stream slope of the dam would be necessary to "hold up the 100-ft. head". As the writer understands experiments of this kind, the purpose should be to determine what hydraulic gradient is required in order to reduce the velocity of the percolating water to such an extent that it will no longer have the power to transport the particles composing the medium through which it percolates. If the circular tank experiments gave any information on this point, the author has not stated it in his paper. Clearly, the "hydraulic gradient of the material" could have been varied at will, either by increasing the head or the area of the outlet at the bottom of the tank, without in any way changing the character of the filling.

The author then assumes in Fig. 8 that the hydraulic gradient under the dam, according to the "line of creep" theory, will be 1 : 9, notwithstanding that this assumption makes the hydraulic grade line intersect the base of the dam well within the toe. The computed hydraulic grade line should intersect the base at the down-stream toe, to be consistent with the "line of creep" theory which the author wished to represent for comparison with the actual tube readings. According to the "line of creep" theory, and the dimensions adopted for the dam, the hydraulic gradient for a 100-ft. head should have been about 1 : 10.5 instead of 1 : 9.

Notwithstanding the foregoing inconsistencies, the author seems to have arrived at a generally safe and economical design for the dam which he had under consideration. Placing the relatively impermeable material on the up-stream face should result in making the hydraulic grade line begin near the toe instead of near the crest as it would have done if the dam had been built entirely of the material with which it was started.

The location of the piling near the center instead of near the up-stream toe is justified if the up-stream slope is not sufficiently tight to exclude the water. With a masonry or other water-tight dam, the piling, of course, should be near the toe.

The combination of local materials, in order to secure maximum density, is noteworthy, and the application of sieve analysis curves to this problem seems to be original. It would be interesting to know the construction methods by which the intimate mixture of the two materials was obtained. Mr. Elliott.

EDWARD WEGMANN,* M. AM. SOC. C. E.—The author is to be congratulated on the scientific manner in which he has worked up the results obtained with his model of an earth dam. Although the paper is interesting in this respect, the speaker does not think that any general conclusions, drawn from the results obtained with such a small model, will be applicable to the construction of a high earth dam. Mr. Wegmann.

In reference to Fig. 9, it is the speaker's opinion that, although in the experiment the water passed along the sheet-pile cut-off to its bottom and then rose again, in a high dam, built according to the model, the water would be very apt to take a short cut and pass over the top, instead of under the bottom, of the piling.

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* New York City.

AMERICAN SOCIETY OF CIVIL ENGINEERS

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PAPERS AND DISCUSSIONS

METHOD OF DESIGNING A RECTANGULAR REINFORCED CONCRETE FLAT SLAB, EACH SIDE OF WHICH RESTS ON EITHER RIGID OR YIELDING SUPPORTS

Discussion.*

By Messrs. E. P. Goodrich, Ernst F. Jonson, and Charles M. Montgomery.

E. P. Goodrich,† M. Am. Soc. C. E. (by letter).—For the last five or six years the writer has used a method of design for flat slab systems of reinforced concrete which takes account of deflections of interior and exterior girders, and even of the bending moments of columns. To be sure, it is more or less approximate, and the final result is secured through a method of continued approximations. Mr. Goodrich.

A start is made with the same assumptions as those by Mr. Janni, that a rectangular slab may be divided into a system of beams at right angles to each other. The live and dead loads are assumed to be concentrated at the intersections of the beams of the two systems. Simultaneous equations have been developed giving the proportional loads supported on each beam of each system computed on the basis of the relative deflections of the several beams and the fact that the total load carried by the two systems must be the total load on the structure.

This method ignores the deformation caused by shear, and all lateral dilation, as measured by Poisson's ratio. Designs have been worked out which include: beams rigidly supported; beams with supports subject to settlement or deflection; beams with settled supports

* Discussion of the paper by A. C. Janni, M. Am. Soc. C. E., continued from April, 1916, *Proceedings*.

† New York City.

Mr. Goodrich. in which the tangent remains at a constant or a changing angle, etc., etc.

It is believed that Mr. Janni has done a service to the Profession by calling attention to the necessity of considering the deflection of supports in ordinary problems of design.

Mr. Jonson. ERNST F. JONSON,* ASSOC. M. AM. SOC. C. E. (by letter).—The author calls attention to two facts which are not generally recognized, *viz.*, that the deflection of the girders and Poisson's ratio enter as determining factors into the calculation of concrete slabs reinforced in two directions. Unfortunately, however, he ignores several equally, or even more, important facts, so that his treatment of the problem can by no means be regarded as a solution. These ignored facts are the following:

The distance, $d\,k$, to the neutral axis of a reinforced concrete beam is not a constant if the concrete shrinks during hardening and drying, and practically all concrete does. The value of k becomes then a function of the moment (unfortunately, a very complex function), varying from 0 for $M = 0$ to the usually assumed values when the moment reaches its maximum. From this fact it follows, of course, that the moment of inertia is not only a constant, but also a function of the moment, decreasing about 50% in value from zero moment to maximum moment. The consequence of this condition, again, is that the theorem of three moments cannot be applied to reinforced concrete, nor any other method which deals in deflection components. The author's method, therefore, is fundamentally erroneous, and so are all calculations of statically indeterminate structures of reinforced concrete. All reinforced concrete construction is statically indeterminate with regard to the stresses, but, in speaking of statically indeterminate construction, the writer means to refer only to cases in which the loads and moments are also statically indeterminate.

In a reinforced concrete slab, the moment of inertia cannot be assumed to be the same in both directions, as is done by the author, because economy demands that less reinforcement be used longitudinally than transversely, and because the two sets of reinforcement cannot be placed on the same level.

The author's method implies the assumption that all moments are at a maximum when the entire floor is covered by the live load. This assumption is erroneous. The moment in the center of the slab is a maximum when the adjoining slabs carry no live load, and the moments over the girders reach their maximum when the live load covers the two panels between which the girders run, but not the adjoining ones.

As the slab is regarded as having fixed edges, its flexure must be one of reversed curvature. The law of variation of loading, therefore,

* New York City.

is more closely approximated by a straight line from end to middle than by a parabola, as assumed by the author. The latter would be the proper approximation for a non-continuous slab merely supported along its edges. Mr. Jonson.

All calculations of reinforced concrete made on the assumption that the ratio, n or E divided by E_c, is a constant are unreliable, because this ratio varies with the time the load is applied, from an initial value somewhat less than that usually assumed to a final value about twice as great as that generally used in reinforced concrete calculations.

It is a question whether enough is known about Poisson's ratio of concrete to justify its use as a constant in a calculation of stresses in reinforced concrete. Short-time tests have given values of from 0.25 to 0.2, but it is not known how much its value might be reduced by prolonged application of load. It may probably fall to 0.1, or even less.

The statement on page 206* that "these beams, *a* and *b*, are carrying the same uniform load" is erroneous. The author probably intended to say, "because the beams *a* and *b* deflect the same, although their lengths are different, they cannot carry the same load."

The author's statement, that when the length is great enough to make $\alpha = 1$ there is no advantage in two-way reinforcement, is misleading, because it implies that there is an advantage in such reinforcement when the length is less. According to the author's method of figuring, even in the most favorable case, *viz.*, the one in which the slab is square, it requires about one-third more reinforcement than a slab reinforced in one direction only. This excess might indeed be reduced by increasing the spacing of the rods toward the edges, but, within the limits fixed by the building law, this could not be carried far enough to produce economy. It would seem, therefore, that when the author says that the advantage of two-way reinforcement is maximum when the slab is square, he should say that the disadvantage is a minimum. The most desirable form of two-way reinforcement would seem to be the so-called flat-slab construction which gives a flat ceiling and requires less form work.

In looking into this problem, the writer finds that the entire theory of reinforced concrete is rather crude, probably owing to the circumstance that, when it was worked out, the properties of concrete were not sufficiently well known to make a reasonably correct theory possible. The theory of flexure of concrete is especially in need of a thorough revision. The present theory is merely an adaptation of the theory of flexure of elastic solids to a material which is subject to permanent deformations several hundred per cent. greater than its elastic deformations. Time has not permitted the writer to make such a revision in the present discussion, but he has attempted to indicate its general direction. Before such a revision can be completed, more exact determina-

* *Proceedings*, Am. Soc. C. E., for February, 1916.

Mr. Jonson. tion must be made of the physical properties of concrete, *viz.*, the true modulus of elasticity, the non-elastic deformation, Poisson's ratio, initial shrinkage during hardening, and subsequent expansion and shrinkage due to variations in absorbed water. In determining these values, the influences of proportions of mixture, wetness of mix, kind, size, and grading of aggregate, age of concrete, degree of wetness during hardening, time of application of load, horizontal or vertical direction of stress, previous loading, etc., must be taken into account.

The great influence which the shrinkage has on the flexure of a reinforced concrete beam calls for the following revision of the formulas. Unless it is immersed in water, concrete shrinks during hardening. This shrinkage may amount to 0.05 of 1 per cent. When concrete is saturated with water, it again expands. This shrinkage, m, has considerable influence both on the resistance and the deflection of a beam. If a concrete beam reinforced in the bottom only is supported by the forms until all the shrinkage has taken place, either the concrete will be in tension and the steel in compression, or the concrete will crack. It is on the safe side to assume the latter. If, then, the forms are lowered slightly, but not enough to cause the beam to carry its own weight, the cracks will close at the top of the beam. When the forms are removed entirely, the concrete in the top of the beam will compress, so as to allow a part of the crack to close until the compressive stress developed in the closed part of the crack multiplied by its leverage, $d\ j$, about the center of the reinforcement is equal to the bending moment produced by the load. It may be seen from the strain diagram (Fig. 3) that:

$$\frac{\frac{f_c\, n}{E}}{\frac{f_s}{E} + m} = \frac{k}{1 - k} \quad \text{(1)}$$

and that, therefore,

$$k = \frac{f_c\, n}{f_s + f_c\, n + E\, m} \quad \text{(2)}$$

and, also, that

$$\frac{f_c\, k}{2} = f_s\, p \quad \text{(3)}$$

$$f_c = \frac{2\, f_s\, p}{k} \quad \text{(4)}$$

p being the steel ratio, which, therefore, is

$$p = \frac{f_c\, k}{2\, f_s} \quad \text{(5)}$$

Mr. Jonson.

Inserting this value of f_c in Equation (1), we have

$$\frac{2\, f_s\, n\, p}{k\,(f_s + E\, m)} = \frac{k}{1 - k} \qquad (6)$$

$$k = \sqrt{\left(\frac{f_s\, n\, p}{f_s + E\, m}\right)^2 + \frac{2\, f_s\, n\, p}{f_s + E\, m}} - \frac{f_s\, n\, p}{f_s + E\, m} \qquad (7)$$

and also from Equation (6), that

$$f_s = \frac{E\, k^2\, m}{2\, n\, p\,(1 - k) - k^2} \qquad (8)$$

$$f_c = \frac{2\, E\, k\, m\, p}{2\, n\, p\,(1 - k) - k^2} \qquad (9)$$

From Fig. 3 it will also be seen that the reacting moment is

$$M = f_s\, b\, d^2\, j\, p = f_c\, \frac{b\, d^2\, j\, k}{2} \qquad (10)$$

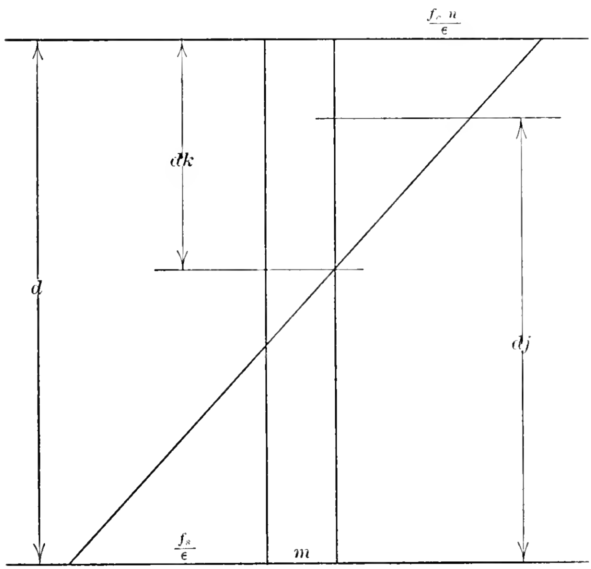

FIG. 3.

With regard to the maximum moment on a beam, the values of f_s and f_c are fixed, and from these follow those of j, k, and p. In 1 : 2 : 4 concrete, the value of $E\, m$ may vary from — 3 000 to 15 000, and that of n from 10 to 30. Hence, if the working stresses are 16 000 for steel

Mr. Jonson. and 650 for concrete, the steel ratio, p, may vary between the following limits:

$E\ m$	n	k	p
—3 000	10	0.333	0.675%
—3 000	30	0.600	1.218%
15 000	10	0.174	0.355%
15 000	30	0.386	0.784%

The greatest steel ratio is required, therefore, when the concrete is kept so wet that it expands slightly during hardening instead of shrinking. All concrete which is allowed to harden in air and finally dry out shrinks more or less, according to the rapidity with which it is allowed to dry. Tests should be made to determine the minimum shrinkage which may be definitely counted on. In the meantime, 3 000 may be assumed as a safe minimum value for $E\ m$, which makes:

$E\ m$	n	k	p
3 000	10	0.255	0.52%
3 000	30	0.507	1.03%

The value of $j\ p$ then varies between the limits:

$E\ m$	n	p	j	$j\ p$
—3 000	10	1.22%	0.889	1.086%
—3 000	30	1.22%	0.800	0.977%
+3 000	10	1.03%	0.915	0.944%
+3 000	30	1.03%	0.831	0.857%
15 000	10	1.22%	0.942	1.150%
15 000	30	1.22%	0.871	1.063%
15 000	10	1.03%	0.942	0.972%
15 000	30	1.03%	0.871	0.897%

This shows that for each steel ratio the strength of a beam increases slightly as it shrinks, but the effect is not marked, the main effect of the shrinkage being felt in determining the steel ratio. The strength also decreases slightly as the permanent set increases, but here, also, the main effect is on the steel ratio. A beam figured by the current method would require a steel ratio of 0.77% instead of from 1.03 to 1.22%, as it should be, and would give a resistance, $j\ p$, of 0.67%, whereas, if figured by the correct formula, the resistance is only 0.62% for a beam kept wet and 0.64% for one hardened under ordinary conditions.

If the correct steel ratio had been used, the strength would have been increased in proportion. In other words, the current method exaggerates the stress on the concrete. Instead of 650 lb. per sq. in., as assumed, there is only 525 lb. It is natural that the continued yielding should reduce the unit stress by increasing the distance to the neutral axis. The higher unit stress which exists for a few hours after applying the load can do no harm, because it is relieved by the yielding of the concrete. On the other hand, the stress on the steel is, of course, correspondingly under-estimated, being actually 16 800 instead of 16 000 as figured. Mr. Jonson.

Tests made by Mr. E. B. Smith, of the U. S. Office of Public Roads, have shown that 1:2:4 concrete stressed to 700 lb. per sq. in. had a modulus of deformation of 2 800 000 lb. per sq. in. immediately after the load was applied, but that this modulus changed its value as follows: in 1 hour to 2 600 000; in 24 hours to 2 000 000; and in 21 days to 1 400 000. A test made by Mr. C. M. Montgomery* in the Laboratory of the New York Board of Water Supply, confirmed these results in a general way. This test was made on a cylinder, 8 in. in diameter and 16 in. high, of about 1:2:4 mix, several years old, and thoroughly air-dried. The unit load was 300 lb. per sq. in. The modulus of elasticity maintained a constant value of about 3 000 000 ($n = 10$), but the total deformation did not become constant until the load had been on for 10 days. The modulus of total deformation, F, varied as follows:

	F.	n.
Initial	3 000 000	10
After 17 hours..............	1 800 000	17
After 2 days................	1 600 000	19
After 4 days................	1 300 000	23
After 7 days................	1 200 000	25
After 10 days...............	1 100 000	27

Mr. F. R. McMillan, of the University of Minnesota, in his paper on "Shrinkage and Time Effects in Reinforced Concrete", gives further confirmation of these facts.

The deflection of a beam is due to the curvature which results from the stretching of the fibers on one side of the neutral axis and the corresponding compression of those on the other side. The angle of inclination thus produced in a very small part of the length, dx, is, therefore,

$$\frac{f_c\,n + f_s + E\,m}{E\,d}\,d\,x \qquad (11)$$

and, hence, if x is taken as the distance to the free end of a cantilever, the deflection is

$$D = \int_0^l \frac{f_c\,n + f_s + E\,m}{E\,d} \times d\,x \qquad (12)$$

* See Mr. Montgomery's discussion of Mr. Janni's paper, page 777.

Mr. Jonson. The moment on the beam may be expressed in terms of k, as follows:

$$M = f_s\, b\, d^2 j\, p = \frac{E\, b\, d^2\, k\, m\, p \left(1 - \frac{k}{3}\right)}{2\, n\, p\, (1 - k) - k^2} \ldots\ldots\ldots\ldots (13)$$

If a diagram is constructed in which the values of k are the abscissas, and the ordinates of two curves, respectively, represent the corresponding values of

$$\frac{M}{E\, b\, d^2\, m},\ \text{and}\ f_c\, n + f_s + E\, m,$$

the value of the latter function which corresponds to a known value of the former may thus be found in a practical manner. If these values are utilized as ordinates in constructing a diagram on the beam, similar to an ordinary moment diagram, the summation required by Equation (12) may be accomplished by treating this diagram as if it were a diagram of a distributed load, the moment of which is wanted about the free end. The free end ordinate thus obtained is equal to

$$\int_o^l (f_c\, n + f_s + E\, m) \times d\, x \ldots\ldots\ldots\ldots (14)$$

In this way the deflection of any beam subject to statically determinate moments may be found. The middle deflection of a beam supported at both ends is found by treating each half as if it were a cantilever and taking the average of the deflections of these. The deflection of any point may be found by this method, if the two end deflections are plotted and then the proportionate deflection found at the dividing point.

The curve of flexure may be constructed by a graphic solution of the equation

$$y = \int_x^l \frac{f_c\, n + f_s + E\, m}{E\, d} (x - x_1)\, d\, x \ldots\ldots\ldots (15)$$

x_1 being the abscissa corresponding to y.

The calculation of a statically indeterminate construction by the foregoing method would be exceedingly laborious, but, fortunately, such forms of construction are very rare in reinforced concrete. Most cases which are treated as indeterminate are not indeterminate at all. Take, for instance, the case of a continuous floor girder extending from one side of a building to the other, a total length of 60 ft., and supported by two columns each 5 ft. from the center. At a point 4 ft. from the column, the reinforcement is carried down from the top to the bottom of the girder. On one side of this point only positive moments are resisted and on the other only negative ones; hence, at the point where the reinforcement crosses the center line, the moment must be zero. The correct method of calculating such a girder is much simpler than by the illegitimate use of the theorem of three or of four moments.* Construct a static moment diagram on each span as if it were discontinuous. Then divide the diagram of the long span by a straight line in such a way that the positive moment at the middle of the suspended span is numerically equal to the negative moment in the double cantilever over the column. Then draw a horizontal line representing the negative moment across the middle span, and the area included between this line and the first moment curve will be the true moment diagram. The point at which the first straight line intersects the moment curve of the side span is, of course, the point at which the reinforcement should cross the center line. Likewise, any other case may be resolved into a system of cantilevers and suspended spans. The only truly indeterminate cases are those in which both the top and the bottom of the beam are reinforced. This is a form of construction which should be avoided on account of the difficulty of calculating it correctly. For the same reason, slabs reinforced in two directions should also generally be avoided, unless the slab can be made square and the problem thus simplified. Mr. Jonson.

When the foregoing observations are applied to the author's problem, it resolves itself into the simpler problem of calculating a cantilever slab extending from each side of the girders and supporting a central suspended panel. If the edges were securely fixed, the projection of the cantilever might be made about 15% of the span, but if the torsional resistance of the girder has to be depended on to carry the live load of one panel when the adjoining panels are not loaded, it would probably have to be less. We have then the problem of finding such a value of the author's coefficient, α, and of a coefficient, β, as shall make the center deflection of the slab the same when figured longitudinally as when figured transversely. When the slab is supported on deflecting girders there enters into the problem also a coefficient, β, representing the percentage of the load which is carried by the beam at its point of support on the girder. The reinforcement in the other direction may carry a part of the live load at this point. This coefficient, β, should be found before α by assuming values of α and β, and then figuring the corresponding deflections of the girder and the beam next to it, which must be equal if the assumptions are correct. In figuring the deflections for the purpose of finding the transverse moments, the longitudinal girders should carry a balanced live load, but the transverse ones should carry no live load on the

* The theorem of four moments is the general form which applies to all cases; the theorem of three moments is applicable only when the two middle moments are of the same magnitude, which they generally are not when the girder is stiffly connected to the columns. See "The Theory of Frameworks with Rectangular Panels," by Ernst F. Jonson, Assoc. M. Am. Soc. C. E., *Transactions*, Am. Soc. C. E., Vol. LV., p. 413.

Mr. Jonson. panel on the other side. In this case, not only the deflection of the girder must be taken into account, but also that of the edge of the cantilever slab due to the twisting of the girder which results from the absence of live load on one side. When figuring with the α and β which give the greatest longitudinal stress, the conditions, of course, are reversed.

It is evident that a direct solution of this problem is impossible, for it is necessary to start with assumed values of α and β, which must be corrected if the deflections do not turn out to be equal in both directions. The influence of lateral strain may be taken account of by adding an imaginary negative load of such magnitude that the strain which it would produce in the concrete is equal to the lateral strain due to the total loading (including the imaginary negative load) on the beam in the other direction; but, in figuring the deflection due to this load, the strain in the reinforced side must be ignored, for Poisson's ratio cannot be applied to the tension side. A reasonably true solution of this problem is thus seen to be very laborious, but if it is worth while solving at all it is worth doing it right. Tables and diagrams may be constructed for practical use.

The initial stress in a reinforced concrete column due to shrinkage is as follows, f_i being the tension in the concrete and f_r the compression in the steel:

$$f_i = f_r\, p$$

$$\frac{f_i\, n}{E} + \frac{f_r}{E} = m$$

$$f_r = \frac{E\, m}{p\, n + 1}$$

$$f_i = \frac{E\, m\, p}{p\, n + 1}$$

These stresses must be added to those due to load and wind. Owing to the general predominance of compressive stress, it makes no practical difference whether or not the concrete cracks. In a column with $p = 4$, and 400 lb. per sq. in. on the concrete—as favorable a case as may be found in current practice—the stress in the steel is

$$f_s = 6\,800 + 8\,700 = 15\,500.$$

If, on the other hand, $p = 0.5$, and the load on the concrete is 500 lb. per sq. in., then

$$f_s = 13\,000 + 14\,000 = 27\,000.$$

This means that, with the current method of figuring, unless a considerable percentage of reinforcement or a low working stress on the concrete is used, the steel is stressed nearly to its elastic limit. On the other hand, the concrete is not stressed very high, such stresses, corresponding to the foregoing cases, being, respectively, Mr. Jonson.

$$f_c = 290 - 272 = -\ 18$$
$$f_c = 468 - \ 65 = \ 403$$

The correct method of calculating a reinforced concrete column, therefore, would be one which takes account of the shrinkage stresses. That is,

$$f_s = f_y + \frac{E\,m}{p\,n + 1}$$

$$f_x\,n = f_y$$

f_x being the available working stress on the concrete and f_y that on the steel. As this formula gives f_y its minimum value for the maximum value of m, $E\,m$ must be given the value 15 000. If $f_s = 20\,000$, we have

$$20\,000 - \frac{15\,000}{30\,p + 1} = f_y$$

$$f_x = \frac{f_y}{n}$$

$$f_c = f_x - \frac{E\,m\,p}{p\,n + 1}.$$

We get then for extreme values of p:

p	f_y	f_x	f_c
4%	13 200	440	167
½%	7 000	233	168

which shows that the concrete is never stressed high in columns, and, for this reason, a rather high stress may be used on the steel.

Charles M. Montgomery,* Esq. (by letter).—The following is a record of a test made in the Laboratory of the New York Board of Water Supply, in connection with the discussion of Mr. Janni's paper by Mr. Ernst F. Jonson. The specimen was a cylinder, 8 in. in diameter and 16 in. high, made at one of the tunnels of the Catskill Aqueduct, from concrete used for lining the tunnel, the mix of which was approximately 1 : 2 : 4. The specimen was made about 4 years ago, and was stored in damp sand until May, 1915, since which time it has been exposed to the air. The coarse aggregate was Fordham gneiss of 2 in. maximum size; the fine aggregate was also Fordham gneiss. The crushing strength was 3 550 lb. per sq. in. Mr. Montgomery.

A narrow iron collar was bolted around each end of the specimen (with a measuring point projecting on each side). The distance

* Inspector, Board of Water Supply, New York City.

Mr. Montgomery.

from center to center of collars was 15 in. This specimen was not made for the purpose of determining deformations, and was therefore deficient in length. The nearness of the collars to the ends undoubtedly reduced the deformation, so that the modulus of elasticity given by this test is probably somewhat high. The purpose, however, was not to establish the value of the modulus of elasticity, but to discover to what extent deformations would continue during a prolonged application of the load. The deformations were measured by two inside micrometers, reading to 0.0001 in., which remained in place during the entire period of the test. The contact between the micrometer and the upper measuring point was indicated by an electric buzzer. The initial load was 10, and the final load 300 lb. per sq. in. Table 1 is a record of the test.

TABLE 1.

Total load, in pounds.	Micrometer.			Deformation.	Time.	
	Front.	Rear.	Average.		Date.	Hour.
500	0.2059	0.1060	0.1556	......	3/22	4 P. M.
1 500	0.2053	0.1032	0.1542	0.0014		
500	0.2046	0.1057	0.1551	0.0005	3/23	9 A. M.
1 500	0.2041	0.1024	0.1532	0.0024		
500	0.2048	0.1034	0.1541	0.0015	3/24	9 A. M.
1 500	0.2047	0.1010	0.1528	0.0028		
500	0.2036	0.1044	0.1540	0.0016	3/25	9 A. M.
1 500	0.2032	0.1009	0.1521	0.0035		
500	0.2039	0.1030	0.1534	0.0022	3/27	9 A. M.
1 500	0.2039	0.1007	0.1523	0.0033		
500	0.2043	0.1033	0.1538	0.0018	3/28	9 A. M.
1 500	0.2038	0.1007	0.1522	0.0034		
500	0.2040	0.1027	0.1533	0.0023	3/29	9 A. M.
1 500	0.2035	0.1004	0.1519	0.0037		
500	0.2040	0.1025	0.1532	0.0024	3/30	9 A. M
1 500	0.2034	0.1003	0.1518	0.0038		
500	0.2035	0.1021	0.1528	0.0028	3/31	9 A. M.
1 500	0.2032	0.0998	0.1515	0.0041		
500	0.2036	0.1022	0.1529	0.0027	4/1	9 A M
1 500	0.2032	0.0999	0.1515	0.0041		
500	0.2040	0.1023	0.1531	0.0025	4/3	9 A. M.
1 500	0.2034	0.0998	0.1516	0.0040		
500	0.2037	0.1022	0.1529	0.0027	4/4	9 A. M.
1 500	0.2032	0.0997	0.1514	0.0042		
500	0.2037	0.1022	0.1529	0.0027	4/5	9 A. M.
1 500	0.2032	0.0997	0.1514	0.0042		

AMERICAN SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

THE ECONOMICAL TOP WIDTH OF NON-OVERFLOW DAMS

Discussion.*

By Messrs. Edward Wegmann and H. L. Coburn.

Edward Wegmann,† M. Am. Soc. C. E. (by letter).—The author has discovered the interesting fact that, for a dam of the type shown in Fig. 4, there is a certain top width which gives the most economical section. One would suppose that the narrower the top width, the smaller would be the area of the profile. Mr. Creager has proved that such is not the case, and the method by which he found the top width giving the most economical profile, is correct, provided he does not insist on a rigid compliance with the usual requirement that the lines of pressures, reservoir full or empty, shall be kept within the center-third of the profile. Mr. Wegmann.

Fig. 5 shows a triangular profile without any top width, which is designed to resist solely the hydrostatic pressure of the water, no attention being paid to shocks from floating bodies or from waves. Upward pressure is not considered in this case. In this profile the lines of pressure, for reservoir full and empty, are, respectively, on the down-stream and up-stream limits of the center-third of the profile, and the latter has, therefore, the minimum area which will comply with the given conditions.

If, however, a thin slice of masonry is cut from the down-stream face of the dam, and placed as a small inverted triangle at the top of the dam, as shown by the shaded area in Fig. 6, it will be found that the dam has been strengthened, even though the width of its base has become slightly less, as the moment around its toe is greater for the small inverted triangle than for the thin slice of masonry. In this

* Discussion of the paper by William P. Creager, M. Am. Soc. C. E., from February, 1916, *Proceedings*.

† New York City.

Mr. Wegmann.

case, therefore, there is a surplus of strength, and the area of the profile can be reduced slightly.

There is, however, a limit to the thickness of the slice of masonry which can be transferred from the front face to the top of the dam, as Mr. Creager has shown. The top width which gives the most economical profile can probably be determined by the differential calculus.

Although it is true that one can obtain, in this manner, a profile (Fig. 6), which has less area than the simple triangular profile (Fig. 5), it does not comply strictly with the given condition for reservoir empty. The effect of the small inverted triangle placed at the top of the dam, is to draw the line of pressure, reservoir empty, slightly outside of the center-third. The extent to which this is done is of no practical importance, but the fact remains that, for the given conditions, the triangular profile (Fig. 5) has the minimum area.

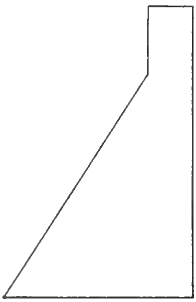

FIG. 4.

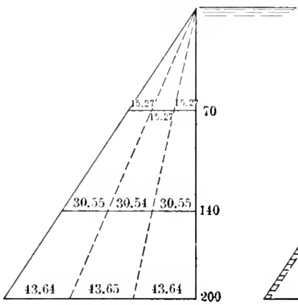

FIG. 5.

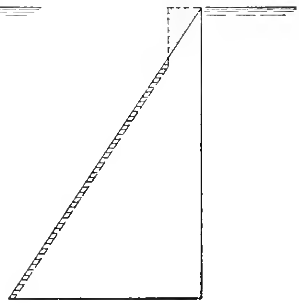

FIG. 6.

If Mr. Creager's rule for the least top width is applied in the design of a dam, this width will have to vary from one end of the dam to the other, according to the height of the structure. This, of course, would never be done in actual practice. Usually, the top width of a masonry dam is not to be determined by theoretical principles, but by practical considerations, such as the strength required to resist shocks from waves or floating bodies, the breadth needed for a roadway over the top of the dam, etc.

Mr. Coburn.

H. L. COBURN,* M. AM. SOC. C. E. (by letter).—This paper was read with much interest by the writer as he had made a study of the same problem, some time previously, but along somewhat different lines. Like Mr. Creager, the writer is not sure that the presentation is of much more than academic interest, but it may give some indication as to why different designers, starting from similar premises, reach such apparently different results in designing the cross-section of a masonry dam.

* New York City.

The writer's method of attack is shown in the accompanying computations, and the results are given in both tabular and graphical form. Mr. Coburn.

The assumptions were as follows:

Specific gravity of masonry 2.3; upward pressure over entire base, varying uniformly from that due to full hydrostatic head at heel to zero at toe; resultant of all forces, reservoir full, must cut base at one-third its length from the toe, that is, there must be no stress at extreme up-stream edge of base. This, of course, assures the minimum section allowable, if the masonry is assumed to have no tensile strength.

The section assumed is made of two right-angle triangles, the fillet which usually would be provided at the junctions of the two triangles in the down-stream face being considered as negligible.

For convenience in making the computations, the width of top was taken in terms of width of base rather than of height, and was expressed by $b = B \div k$; the width of the base was then calculated for various values of k. It should be noted that, for all values of k greater than about 2.6, or top less than 0.4 of the base, or 0.3 of the height, there is only a small variation in the area of the cross-section, with the area a minimum, when the top is about 0.25 of the base or 0.2 of the height. For this section, the base is 0.81 of the height. The average pressure on the base, with reservoir full, is 45 H, in pounds per square foot, and the maximum at the toe is twice this, or 89 H, in pounds per square foot. With the reservoir empty, the average pressure will be 76 H; the maximum at the heel will be 157 H, and the minimum at the toe —4.5 H. Indeed, it should be noted that, with a vertical up-stream face and any width of top greater than zero and less than one-half the base, there will always be some tension at the toe when the reservoir is empty, but this will usually be negligible.

It is of interest, also, to note that, for all widths of top less than one-half, the ratio of horizontal to vertical forces is very high, indicating the necessity of great care in providing means to prevent sliding.

Inspection of Table 5 will make it clearly apparent that, with a simple triangular section, that is, zero width of top, a dam so designed will be equally stable at all portions, regardless of height, and the stresses in the masonry and on the foundations will be a maximum at the greatest section. It is equally apparent that, with a top of any considerable width, a dam, having a maximum section designed in accordance with these figures, will be least stable at its point of greatest height where the resultant will just cut the middle-third.

Consider the section as made up of two triangles, as shown in Fig. 7, the fillet at a being negligible.

Mr. Coburn.

TABLE 5.—FUNCTIONS OF SECTION, IN TERMS OF HEIGHT, FOR VARIOUS WIDTHS OF TOP, ASSUMING UPWARD PRESSURE ON BASE VARYING UNIFORMLY FROM FULL HYDROSTATIC HEAD AT HEEL TO ZERO AT TOE.

k	r	R	C	A	P_1	P_2	P_3	P_4	F
1.0	1.0	0.877	0.877	0.877	112.50	143.75	143.75	143.75	0.317
1.2	0.83	0.615	0.738	0.623	90.58	121.79	177.03	66.54	0.458
1.4	0.71	0.508	0.712	0.539	77.31	108.52	185.64	31.58	0.567
1.5	0.67	0.474	0.711	0.516	72.56	103.79	186.43	19.16	0.604
1.6	0.63	0.445	0.712	0.495	66.68	99.95	185.83	14.03	0.640
1.8	0.56	0.400	0.720	0.472	62.81	93.78	182.72	4.93	0.690
2.0	0.5	0.365	0.730	0.459	58.63	89.86	179.69	0.00	0.730
3.0	0.33	0.262	0.787	0.436	48.63	79.85	165.04	− 5.32	0.816
4.0	0.25	0.203	0.812	0.432	45.13	76.24	157.24	− 4.48	0.854
5.0	0.20	0.166	0.831	0.432	43.50	74.75	152.96	− 3.45	0.865
6.0	0.17	0.141	0.843	0.433	42.63	73.87	150.41	− 2.66	0.870
8.0	0.13	0.107	0.856	0.435	41.75	73.00	147.67	− 1.68	0.874
10.0	0.10	0.086	0.864	0.436	41.38	72.59	146.34	− 1.15	0.875
∞	0.00	0.000	0.877	0.439	40.63	71.88	143.75	0.00	0.877

k = Ratio of base to top;
r = " " top to base $= \frac{1}{k}$;
R = " " " " height;
C = " " base to height, $B = CH$;
A = Area of cross-section, in terms of square of height, area $= AH^2$
P_1 = Average pressure on base, reservoir full, in terms of height, $P_{av.} = P_1 H$
P_2 = " " " " " empty " " "
P_3 = Maximum " at heel " " " " "
P_4 = Minimum " at toe " " " " "
(P_1 to P_4: All in pounds per square foot.)
F = Ratio of horizontal to vertical forces.

Assume an upward pressure on the base equal to the full hydrostatic head at the heel, decreasing uniformly to zero at the toe.

The resultant, with reservoir full, is to cut the base at the down-stream one-third point; that is, no stress at the heel.

The problem is to find the width of the base, B, in terms of the height, H, with varying widths of the top, $b = B \div k$.

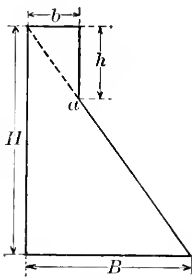

FIG. 7.

Take moments about the down-stream one-third point, as ΣM about this point must equal 0 to meet conditions imposed.

$$\text{Moment of horizontal pressure} = \frac{w\ H^2}{2} \times \frac{H}{3} = \frac{w\ H^3}{6}$$

$$\text{Moment of upward pressure} = \frac{w\ H\ B}{2} \times \frac{B}{3} = \frac{w\ H\ B^2}{6}$$

Moment of weight of lower triangle =

$$\frac{2.3\ w\ H\ B}{2} \times \frac{B}{3} = \frac{2.3\ w\ H\ B^2}{6}$$

Moment of weight of upper triangle =

$$\frac{2.3\ w\ h\ b}{2} \times \left(\frac{2\ B}{3} - \frac{2\ b}{3}\right) = \frac{4.6\ w\ H\ B^2}{6} \left(\frac{k-1}{k^3}\right)$$

Mr. Coburn.

$$\Sigma M = H^3 + H B^2 - 2.3 H B^2 - 4.6 H B^2 \left(\frac{k-1}{k^3}\right) = 0$$

$$B = H \left(1.3 + 4.6 \frac{k-1}{k^3}\right)^{-\frac{1}{2}} = C H \ldots\ldots\ldots\ldots (1)$$

Second.—Area of cross-section in terms of height:

$$A = \frac{1}{2}(B H + b h) = \frac{1}{2}\left(C H^2 + \frac{C H^2}{k^2}\right) = \frac{C H^2}{2}\left(1 + \frac{1}{k^2}\right) \ldots (2)$$

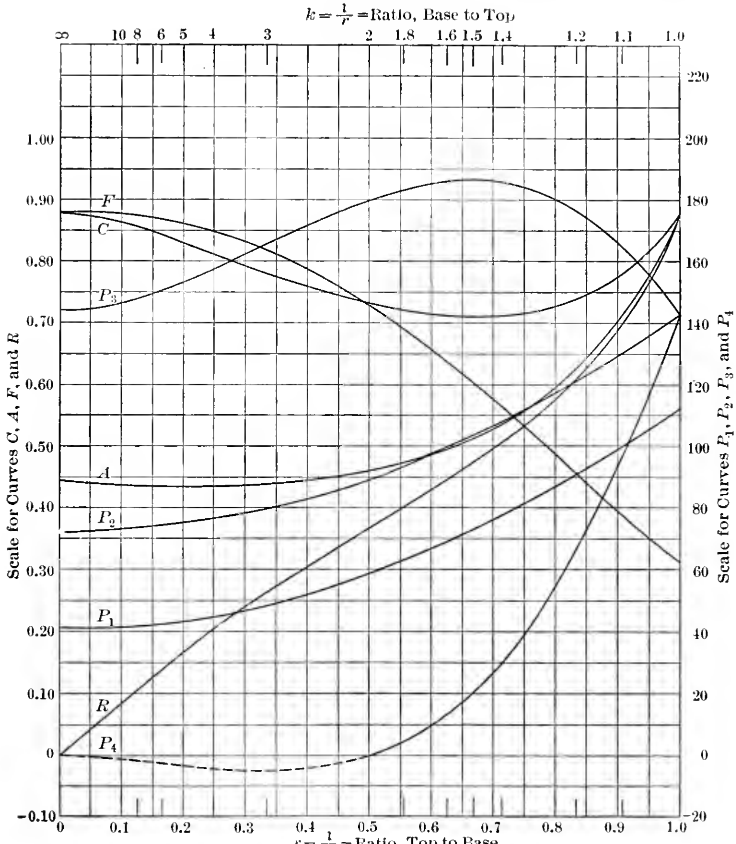

Fig. 8.

Third.—Pressure on base, reservoir full: (From the conditions imposed, maximum at the toe, 0 at the heel).

Take moments about the center of gravity of the base:

$$\text{Moment of horizontal pressure} = \frac{w H^2}{2} \times \frac{H}{3} = \frac{w H^3}{6}$$

Mr. Coburn.

Moment of upward pressure $= \frac{w\ H\ B}{2} \times \frac{B}{6} = \frac{w\ H\ B^2}{12}$

Moment of weight of lower triangle =

$$\frac{2.3\ w\ H\ B}{2} \times \frac{B}{6} = \frac{2.3\ w\ H\ B^2}{12}$$

Moment of weight of upper triangle =

$$\frac{2.3\ w\ h\ b}{2} \times \left(\frac{B}{2} - \frac{2\ b}{3}\right) = \frac{2.3\ w\ H\ B^2}{12}\left(\frac{3\ k - 4}{k^3}\right)$$

$$\text{Reaction} = P_{av.}\ B \times \frac{B}{6} = \frac{P_{av.}\ B^2}{6}$$

Equate, multiply by 6, and divide by B^2, and we get

$$P_{av.} = w\ H\left[\frac{1}{C^2} + \frac{1}{2} - 1.15\ \left(1 + \frac{3\ k - 4}{k^3}\right)\right] = P_1\ H \ldots. (3)$$

$P_{max.}$ = twice $P_{av.}$

Fourth.—Pressure on base, reservoir empty:

Take moments about the center of gravity of the base.

Moment of weight of lower triangle =

$$\frac{2.3\ w\ H\ B}{2} \times \frac{B}{6} = \frac{2.3\ w\ H\ B^2}{12}$$

Moment of weight of upper triangle =

$$\frac{2.3\ w\ H\ B}{2\ k^2}\left(\frac{B}{2} - \frac{2\ B}{3\ k}\right) = \frac{2.3\ w\ H\ B^2}{12}\left(\frac{3\ k - 4}{k^3}\right)$$

$$\Sigma\ W = \frac{2.3\ w\ H\ B}{2}\left(1 + \frac{1}{k^2}\right);\quad \Sigma\ M = \frac{2.3\ w\ H\ B^2}{12}\left(1 + \frac{3\ k - 4}{k^3}\right).$$

$$\text{Moment of arm of resultant} = \frac{\Sigma\ M}{\Sigma\ W} = \frac{B}{6}\left(\frac{k^3 + 3\ k - 4}{k^3 + k}\right)$$

or

$$e = \frac{C\ H}{6}\left(\frac{k^3 + 3\ k - 4}{k^3 + k}\right) \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Now, the average pressure on the base $= \Sigma\ W \div B$

$$= P_2\ H = \frac{2.3\ w\ H}{2}\left(1 + \frac{1}{k^3}\right) = 1.15\ w\ H\left(1 + \frac{1}{k^3}\right) \ldots\ (5)$$

$$P_3 = (P_{max.}) = P_2\left(1 + \frac{6\ e}{B}\right) = 1.15\ w\ H\left(1 + \frac{1}{k^3}\right)\left(1 + \frac{k^3 + 3\ k - 4}{k^3 + k}\right)$$

$$= 2.3\ w\ H\ \left(\frac{k^3 + 3\ k - 2}{k^3}\right) \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

$$P_4 = (P_{min.}) = P_2\left(1 - \frac{6\ e}{B}\right) = 1.15\ w\ H\left(1 - \frac{1}{k^3}\right)\left(1 + \frac{k^3 + 3\ k - 4}{k^3 + k}\right)$$

$$= 2.3\ w\ H\ \frac{2 - k}{k} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Mr. Coburn.

Fifth.—Ratio of horizontal to vertical forces:

$$F = \Sigma H \div \Sigma V$$

$$= \frac{w\ H^2}{2} \div \left(\frac{2.3\ w\ H\ B}{2} + \frac{2.3\ w\ H\ B}{2\ k^2} - \frac{w\ H\ B}{2}\right)$$

$$= \frac{H}{B}\left(\frac{k^2}{1.3\ k^2 + 2.3}\right) = \frac{1}{C}\ \frac{k^2}{1.3\ k^2 + 2.3} \qquad \text{............(8)}$$

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

A STUDY OF THE DEPTH OF ANNUAL EVAPORATION FROM LAKE CONCHOS, MEXICO

Discussion.*

By Messrs. M. Hegly, Robert E. Horton, and J. W. Ledoux.

M. Hegly,† Esq. (by letter).—The writer has examined this paper with much interest and profit, and believes it to be a most valuable contribution to the study of the subject of evaporation from the surfaces of lakes and reservoirs. The results are in remarkable accord with those obtained by other observers, especially with those of Professor Bigelow at Salton Sea. The great care exercised in obtaining the data makes them most valuable. Mr. Hegly.

It is a well-known fact that, until quite recently, the figures given in special treatises and engineering handbooks, on the subject of the quantity of water evaporated from small basins, have not been applicable to large bodies of water, such as lakes, storage ponds built for irrigation works, hydraulic power, or for supplying water to navigation canals. That the figures were too large was well known, but there have been no accurate data which would enable one to calculate with sufficient approximation the actual depth of evaporation which would reduce, in reasonable proportion, the volume of water impounded. There was lacking a rule to be applied to any particular case for using the data obtained from observations, necessarily made on very small surfaces, either by using the formulas given in works on physics or the results obtained in other localities.

Having occasion to solve a similar problem in Tunis during the construction of a large reservoir near the city of that name, the writer assumed that the depth of the annual evaporation would reach 1.60 m.

* Discussion of the paper by Edwin Duryea, Jr., M. Am. Soc. C. E., and H. L. Haehl, Assoc. M. Am. Soc. C. E., continued from April, 1916, *Proceedings*.

† *Ingénieur en Chef, Ponts et Chaussées, Departement de la Haute-Marne, Chaumont (Haute-Marne), France.*

Mr. Hegly. (63 in.); this figure was based on guesswork, however, as the writer does not pretend that he has the perspicacity of Mr. Freeman, who, in 1911, before any local observations and studies had been made, fixed the evaporation from Lake Conchos at 1.40 m. (55 in.).

The only data at the writer's disposal were those given by Professor Ginestous, who, in his "Etudes sur le Climat de la Tunisie", fixes the annual depths of evaporation at 2.255 m. (88.8 in.), a value evidently much too large; for June, July, and August he determined the value 0.72 m. (28.3 in.), a figure which the writer has verified by observations on vats, 4 m. (13.12 ft.) in diameter, placed on the site of the proposed reservoir. It may be of interest to note that during the sirocco a daily evaporation of from 13 to 16 mm. (½ to ⅝ in.) was observed.

The writer also had at his disposal data relative to the depth of evaporation from the surfaces of large stretches of water near the shores of the Mediterranean observed by M. Salles, *Inspecteur Général, Ponts et Chaussées,** who, as early as 1883, was led to believe that the depth of the annual evaporation at Arles, at the northerly point of the plains of Carmague, 25 km. (15½ miles) from the sea-coast, was 1.05 m. (41.3 in.), and prior observations made by the meteorologists fixed the annual evaporation at 1.876 m. (73.8 in.) for Orange and 2.563 m. (100.9 in.) for Arles.

Very careful studies by the engineers of the *Ponts et Chaussées* in Algeria also supplied valuable data; and their long series of experiments at the storage reservoirs of Djebel-Ouach, which supply the City of Constantine (at an elevation of 650 m. (2 132 ft.) and 65 km. (40 miles) from the sea) determined the depth of annual evaporation for the vicinity of that city to be 0.85 m. (33.5 in.) during the winter and 1.40 m. (55 in.) during the summer, or equal to an annual depth of 2.25 m. (88.5 in.). Undoubtedly, this quantity is too large, and must be corrected for seepage, which cannot be neglected at this point. M. Thévenet, *Directeur de l'École des Sciences d'Alger,* in "l'Essai de Climatologie Algérienne", has reduced this figure to 2 m. (78¾ in.). The writer's observations, however, lead him to believe that 1.60 m. (63 in.) is not far from the correct figure, if the altitude, the mean temperature, and the distance from the sea-coast of the country in the vicinity of Tunis are taken into consideration.

M. Thévenet, after some very elaborate experiments to determine the evaporation in the shade as well as in the sun, reached the following conclusions:

In the shade (direct measurement).........	1.014 m. (39.9 in.)
Observed with the Piche evaporimeter.....	1.533 m. (60.3 in.)
In the sun (direct measurement)..........	1.917 m. (75.5 in.)

* *Annales des Ponts et Chaussées*, 1911, Vol. II, p. 425.

Mr. Hegly.

If one is satisfied to use the results of the Piche evaporimeter, he can calculate the evaporation from the surface of a pan similar to those used by M. Thévenet by multiplying by the ratio $\frac{1.917}{1.533}$. From this there is then to be computed the evaporation from the surface of a large reservoir, and the conclusions reached by Messrs. Duryea and Haehl will be of great value for such calculations.

The writer considers as most useful the results obtained from the evaporating pans, both floating and placed on the ground, and especially valuable the percentage, 62 (Conclusion (*c*)), which must be applied to the depth of evaporation from a floating pan in order to get the evaporation from the surface of a large reservoir. On first thought, one is surprised that such a large reduction as 62% must be made, as one would naturally think that the depth of evaporation from the surface of the lake would be the same as that in the pans. There can be no doubt, however, as to the accuracy of this quantity, as the paper has considered the problem from all points of view, and, as the work has been thoroughly checked, the results can be used with confidence, provided the apparatus are of the same shape and dimensions as those described and are set in the same way.

Conclusions (*d*) and (*e*) are most useful, as they show how the evaporation varies with the temperature and the altitude, enabling one to determine the probable evaporation at any place by using data obtained by direct observation in other regions. Diagrams (*a*) and (*b*), Fig. 4, will be of great use for such calculations. They can also be used with Professor Bigelow's formula, by writing $C_2 = 0.024$, which seems to be quite exact.

It is of great value to know how the annual depth of evaporation is divided throughout the months, as such information will enable the observer to limit his observations to a few months of the year, and, in regions similar to northern Africa, in particular, where it seldom rains during the summer, it is most important to know the depth of evaporation during the dry months, which is not compensated for by the rainfall, the precipitation during the winter being about equal to the evaporation. A comparison of the percentages observed at Lake Conchos (page 1739*) and those deduced from the figures by M. Salles, obtained at Arles, is made in Table 77.

The percentages of the depth of evaporation during the summer are higher at Arles than at Lake Conchos, and this should be the case in all regions with hot and dry summers.

As a further proof of the statement in the paper in regard to the retarding influence of the white vapor on the surface of the water, one can refer to a phenomenon observable in winter, which is the

* *Proceedings*, Am. Soc. C. E., for September, 1915.

Mr. Hegly. reverse of evaporation, namely the surface condensation following a cold spell, which lowers the temperature of the water to 0° cent.; then, if this cold snap is followed by a rise in temperature with an increase in the humidity of the air, the aqueous vapor contained in the atmosphere will condense at the surface of the water, and without any precipitation a slight rise in the water level can be observed. M. Angot, *Directeur du Bureau Central Météorologique de France*, was the first to note this phenomenon.*

TABLE 77.

Month.	Lake Conchos.		Arles.	
	Height, in centimeters.	Percentage.	Height, in centimeters.	Percentages.
January	6.6	4.8	3	2.9
February	7.9	5.6	4	3.8
March	10.4	7.4	7	6.7
April	13.2	9.4	8	7.6
May	16.0	11.5	12	11.4
June	16.3	11.7	14	13.3
July	17.0	12.2	18	17.1
August	15.5	11.1	15	14 3
September	13.2	9.4	10	9.5
October	10.7	7.7	7	6.7
November	7.1	5.1	4	3.8
December	5.8	4.1	3	2.9
Totals	1.397 m., or 55 in.	100	1.05 m., or 41 in.	100

The conclusion reached by Professor Bigelow, and quoted by Mr. Robson, that the evaporation from a slightly brackish water, as that of Salton Sea, is about 2% less than that from fresh water, is correct. As early as 1850, it was noticed that near Marseilles the evaporation from salt-water pans was from 4 to 6% less than that from fresh-water pans.

Mr. Horton. ROBERT E. HORTON,† M. AM. SOC. C. E. (by letter).—On reading this paper the writer was disappointed to find that no records of vapor pressure were kept during the somewhat brief experiments on which the authors base their rather elaborate conclusions, in part at least. The authors present numerous diagrams intended to illustrate the variation of evaporation coincident with varying temperature. They infer that although there are numerous factors affecting evaporation and with which it is more or less correlated, the predominant correlation is with temperature. It has long been known that measured evaporation losses from water surfaces could be represented graphically in a fairly satisfactory manner in terms of temperature alone as the

* *Annales du Bureau Central, Mémoires*, 1894, p. 120.

† Albany, N. Y.

independent variable. Diagrams similar to those appearing in the paper have been presented, for example: by C. E. Grunsky, M. Am. Soc. C. E.,* by Philip À Morley Parker,† M. Am. Soc. C. E., and by Adolph E. Meyer,‡ M. Am. Soc. C. E., who gives several such diagrams. Mr. Horton.

For the purpose of determining the relation of evaporation to temperature, considering the latter as the only independent variable, the writer has tabulated the experimental data for Albuquerque, N. Mex., from the records of the Hadley Climatological Laboratory, as appearing on Plate XXXI, and has computed therefrom the correlation coefficient, using the formula:

$$K_C = \frac{\Sigma (\varDelta_T \varDelta_E)}{\sqrt{\Sigma (\varDelta^2_T) \Sigma (\varDelta^2_E)}},$$

where $\varDelta_T$ = the difference between each observed temperature and the mean temperature,

and $\varDelta_E$ = the difference between each observed evaporation and the mean evaporation.

The computations are given in Table 78, and indicate a correlation coefficient, 0.92 in this instance. The probable error of a single observation by the usual formula is 0.0189. If there is perfect correlation between two quantities, the correlation coefficient should be unity. If there is no correlation, it would be zero. If the correlation coefficient is five to six times as great as the probable error and is also greater than one-half or two-thirds in absolute value, it indicates a considerable degree of correlation. This calculation appears to indicate that evaporation in the long run may be treated as though it were a function of temperature alone at a given locality. It is true, however, that in any individual period, as for a given month or year, the evaporation is very profoundly modified by other factors, such as variation in the wind velocity and vapor pressure in the air.

The writer does not intend to offer any discussion of that portion of the paper which relates to the fundamental object which the authors had in mind, namely, to determine the mean annual evaporation loss from Lake Conchos, nor does he desire to be taken as concurring or acquiescing in either the methods or conclusions in that portion of the paper. Entirely aside from that, the work done in attempting a correlation of evaporation with temperature and altitude represents a start in a much needed investigation, and contains suggestions which may be useful in solving the vexed problem of the relation of evaporation to altitude.

* *Engineering News*, August 13th, 1908.

† "The Control of Water", 1913, p. 199.

‡ "Computing Run-off from Rainfall and Other Physical Data", *Transactions*, Am. Soc. C. E., Vol. LXXIX, p. 1056.

Mr. Horton.

TABLE 78.—CORRELATION OF EVAPORATION AND TEMPERATURE, ALBUQUERQUE, N. MEX.

(1) T	(2) Δ_T	(3) Δ^2_T	(4) E	(5) Δ_E	(6) Δ^2_E	(7) $(\Delta_T \Delta_E)$	(8) Month.
40.6	+ 14.9	222.01	2.63	+ 4.56	20.79	+ 67.94	Feb., 1900
49.1	+ 6.4	40.96	6.17	+ 1.02	1.04	+ 6.53	Mar
52.0	+ 3.5	12.25	6.82	+ 0.37	0.14	+ 1.30	Apr.
67.0	— 11.5	132.25	10.08	— 2.89	8.35	+ 33.28	May
76.3	— 20.8	432.64	12.63	— 5.44	29.59	+ 113.15	June
79.1	— 23.6	556.96	11.78	— 4.59	21.07	+ 108.32	July
75.0	— 19.5	380.25	10.21	— 3.02	9.12	+ 58.89	Aug.
67.7	— 12.2	148.84	8.00	— 0.81	0.66	+ 9.88	Sept.
56.8	— 1.3	1.69	4.38	+ 2.81	7.90	— 3.65	Oct.
44.7	+ 10.8	116.64	1.73	+ 5.46	29.81	+ 58.97	Nov.
34.6	+ 20.9	436.81	1.40	+ 5.70	32.49	+ 119.13	Dec., 1900
35.4	+ 20.1	404.01	2.04	+ 5.15	26.52	+ 103.52	Jan., 1901
36.3	+ 19.2	368.64	1.81	+ 5.38	28.94	+ 103.30	Jan., 1903
34.6	+ 20.9	436.81	2.07	+ 5.12	26.21	+ 107.01	Feb.
47.2	+ 8.3	68.89	5.21	+ 1.98	3.92	+ 13.43	Mar.
56.5	— 1.0	1.00	10.05	— 2.86	8.18	+ 2.86	Apr.
62.4	— 6.9	47.61	10.98	— 3.79	14.36	+ 26.15	May
68.4	— 12.9	166.41	11.33	— 4.14	17.14	+ 53.41	June
75.2	— 19.7	388.09	12.36	— 5.17	26.73	+ 101.85	July
74.2	— 18.7	349.69	11.73	— 4.54	20.61	+ 84.90	Aug.
64.0	— 8.5	72.25	9.65	— 2.46	6.05	+ 20.91	Sept.
53.9	+ 1.6	2.56	6.62	+ 0.57	0.32	+ 0.91	Oct.
42.4	+ 13.1	171.61	4.21	+ 2.98	8.88	+ 39.04	Nov.
33.7	+ 21.8	475.24	1.88	+ 5.31	28.20	+ 115.76	Dec., 1903
36.4	+ 19.1	364.81	2.28	+ 4.91	24.11	+ 93.78	Jan., 1904
50.8	+ 4.7	22.09	3.92	+ 3.27	10.69	+ 15.37	Feb.
57.2	— 1.7	2.89	7.48	— 0.29	0.08	+ 0.49	Mar.
58.2	— 2.7	7.29	10.71	— 3.52	12.39	+ 9.50	Apr.
65.0	— 9.5	90.25	12.53	— 5.34	28.51	+ 50.73	May
71.3	— 15.8	249.64	13.03	— 5.84	34.10	+ 92.27	June, 1904
M. 55.5	371.6 Σ	6 171.08	*M.* 7.19	109.29 Σ	486.9 Σ	+ 1 598.9	

The authors are clearly in error in their statement on page 1725* that "Evaporation data in Mexico were entirely lacking." A record of evaporation from two evaporimeters, one in the open, the other in the shade, has been maintained for a number of years by Mr. Manuel E. Pastrana, Director of the Central Meteorological Observatory, the City of Mexico. As this station has an altitude of 7 450 ft. above tide, the results would appear to have been of considerable value in the preparation of this paper, especially in the matter of the relation of evaporation to altitude.

The meteorological data mentioned comprise records by months, for 1895 to 1901, inclusive, for the following: Reduced mean barometer, mean air temperature in the shade and in the open, mean temperature of the soil 2.79 ft. deep, and of water, mean vapor tension in the shade and in the open, mean daily evaporation in the shade and in the open, mean wind velocity and precipitation; and, for 1902 to 1904,

* *Proceedings*, Am. Soc. C. E., for September, 1915.

inclusive, the mean air temperature, relative humidity, precipitation, and evaporation in the shade and in the open.* Mr. Horton.

Unfortunately, the writer has not had opportunity to compile these records for the years subsequent to 1904. It will be noted that they include, not only the evaporation from water surfaces under two different conditions, but all the attendant meteorologic data necessary for an interpretation of the results. The evaporation pans are each 8.86 in. in diameter and 4 in. deep. The one in the open stands on the flat roof of a house, the one in the shade is in a corridor with window blinds. The anemometer is on the roof of the house, at a height a little greater than that of the exposed evaporimeter. The pans are filled each morning to a definite level. The water temperature is taken in a large tank or water reservoir, and not in the evaporation pan.

In addition to these extensive and carefully maintained records of evaporation in Mexico, a number of other evaporation stations were established, and similar records of evaporation kept. The writer has at hand the detailed results at the following stations for 1904: Guanajuato (Gto.), Toluca (Mex.), Morelia (Mich.) (Seminario), San Juan Bautista (Tab.), Puebla (Pue.) (Colegio del Estado), Queretaro (Qro.) (Colegio Civil), Merida (Yuc.), Guadalajara (Jal.), Pachuca (Hgo.), Mazatlan (Sin.), Chignahuapam (Pue.), Leon (Gto.), Chihuahua (Chih.), Zacatecas (Zac.), Vera Cruz (Ver.) (S. Juan de Ulua).

The authors quote Professor Bigelow's formula in metric units and give certain coefficients in connection therewith, but, apparently without making any use of this formula in the paper. Those who wish to examine the results of Professor Bigelow's investigations on evaporation should consult *Boletin No. 2*, Oficina Meteorologica Argentina, 1912, or Bigelow's recently issued "Treatise on Meteorology, etc." In these later works, many of Bigelow's tentative conclusions appearing in the earlier papers cited by the authors and others in this paper have been rejected or modified.

The work of the authors may be classed as almost wholly empirical. Far-reaching extrapolations are made from somewhat limited data. Methods are often justified in investigations for specific purposes where it is absolutely necessary to reach some conclusion, but are not justifiable in any attempt to arrive at broad scientific generalizations. The writer feels that the subject of evaporation may be attacked to better advantage by one first having grounded himself thoroughly in the physical principles underlying the phenomena, and thereafter following these principles as closely as possible and doing away with wholly empirical methods where practicable.

* Tables containing these data have been filed in the Library of the Society, and copies may be obtained by any one interested.

Mr. Horton. In this paper the specific result seems first to have been arrived at by guesswork. The authors, by repeatedly calling attention to this guess, as if it in reality was of some value as corroborating their results, have, unfortunately, and no doubt unintentionally, created the appearance that their investigation was for the purpose of corroborating the original guess. It is a fact that any physical quantity capable of direct measurement, even though its value in a particular instance is wholly unknown, will very often lie close to the mean of three or four good guesses made independently by men of some experience in measuring the quantity in question. It does not follow that guesswork should be substituted for measurement, and, as a general rule, where scientific results are to be obtained, it seems preferable to avoid if possible pre-influencing the mind by having any fixed figure set up in advance.

Mr. Ledoux. J. W. LEDOUX,* M. AM. SOC. C. E. (by letter).—The writer has looked over this paper, but has not had time to study it carefully or even read all the other discussions which, no doubt, are very valuable, but is impressed with the idea that the conclusions in the paper may be seriously misleading.

In 1888 and 1889 the writer made weather observations, which included the measurement of evaporation on a water surface containing about 25 acres, in the Allegheny Mountains. Observations were made at least once a day. The apparatus consisted of a 6-in. pipe, 2 ft. long, with a wooden collar at the top forming a float. A shallow wooden box, some 4 or 5 ft. square, with an 8-in. hole in the center, was provided, and this formed an outside shield to hold the 6-in. pipe vessel. The whole apparatus was floated in the water and anchored at various points in the reservoir. The object of the box was to prevent, as much as possible, the wind from emptying the evaporating vessel. With the aid of a boat, measurements were then made with a hook-gauge from a fixed point at the top of the collar. The evaporating vessel was kept as full as possible, say, within ½ in. of the top. Occasionally, the results were lost on account of wind and rain.

In order to find out whether the results obtained in the reservoir had any relation to those on land, evaporating vessels, each consisting of a length of 18-in. terra cotta pipe with water-tight bottom, were sunk in the ground, so that their top surfaces were level with its surface and slightly above the level of the water in the reservoir, and having about the same exposure as the reservoir itself. Observations on these were continued for some months, simultaneously with barometer, wet-and-dry-bulb thermometer, direction and intensity of wind, sunlight, etc.

* Philadelphia, Pa.

Up to that time, the writer was under the impression that the evaporation from water surfaces was more directly related to relative humidity than to any other factor, but one month's observations absolutely dispelled this belief. Mr. Ledoux

The final conclusions were that evaporation depends almost entirely on the temperature and the wind, and has very little relation to humidity, even where the relative humidity varies between 70 and

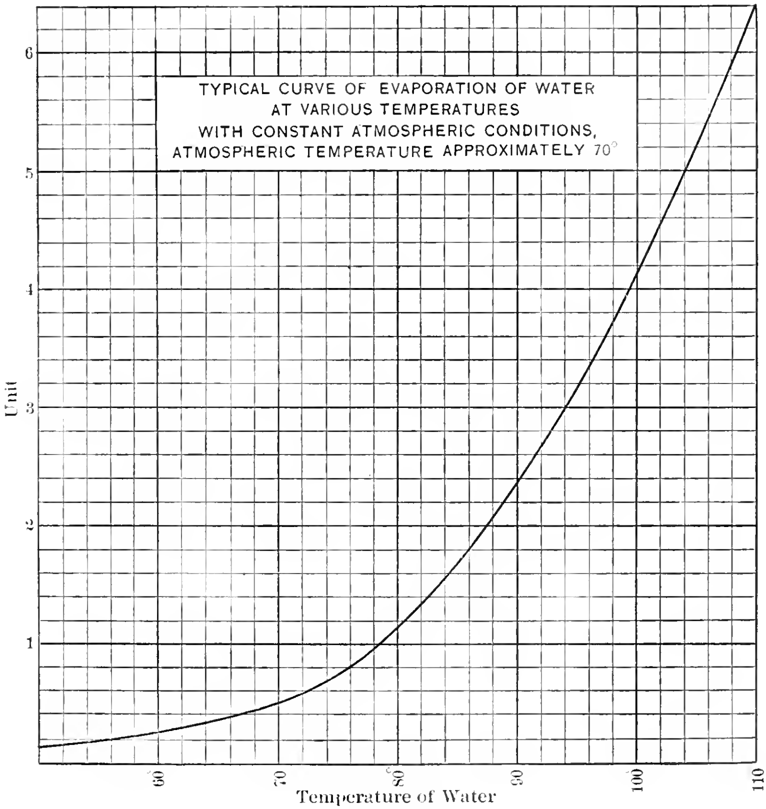

FIG. 31.

95%; that land gauges give the same results as floating gauges, provided the temperature of the water in the evaporating vessel is kept the same as that of the water in the reservoir; that a gauge 6 in. in diameter will show as much evaporation as one 18 in. in diameter; that it is important that the evaporating vessel be kept full, so as to get a complete water exposure; that the best way to measure the evaporation is to fill the vessel with a pipette at the same time every

Mr. Ledoux. day, so that the surface of the water will come up to the same point or hook. The number of inches of evaporation can then be determined by a constant multiplied by the number of cubic centimeters poured into the evaporating vessel.

The writer is under the impression that the evaporation from a water surface is affected materially by humidity where the relative humidity is less than 70 per cent.

In one series, near Charleston, S. C., kept under the direction of the writer from 1903 up to the present time, there are two evaporating gauges. One is exposed to the air, about 5 ft. above the ground and covered with a glass 1 or 2 in. above the top of the vessel; the other is kept at the level of the water in the reservoir. The exposed vessel sometimes shows results 50% higher than the reservoir vessel, but it is of great value, because it is always available, even when the other is lost by wind or rain, and by comparing with the results before and after, correct inference is thereby obtained for the time lost. The average annual evaporation was approximately 53 in.

The diagram, Fig. 31, shows the relative evaporation from a water surface under practically constant temperature and conditions of the atmosphere for equal intervals of time, but with varying temperatures of the water. As an example, it will be seen that, if the temperature remains constant, if the water has a temperature of 80°, the evaporation would be 0.4 in. in 24 hours. If the temperature were increased to 110°, the evaporation would be 2.31 in. The tests on which this diagram is based were made with an atmospheric temperature of about 70° Fahr.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

DISCUSSION ON FLOODS AND FLOOD PREVENTION*

BY MESSRS. H. M. CHITTENDEN AND MYRON L. FULLER.

H. M. CHITTENDEN,† M. AM. SOC. C. E. (by letter).—The writer does not fully understand the purpose of a report of this character, whether it is simply to remain as the findings of the Committee, or, after discussion, to be adopted, with possible modification, as an official expression by the Society. There are certain reasons why the latter course, if practical unanimity could be arrived at, would seem, at the present time, to be particularly desirable. From this point of view, the writer will contribute his mite toward the further elucidation of certain features of the Committee's able treatment of the subject. Mr. Chittenden.

Terminology.—First, as to terminology and verbiage: Ought not "control" to replace "prevention" in the title? Prevention is not broad enough. Levees, for example, do not prevent floods (they actually increase gauge height and discharge), but they control them. Reservoirs prevent, or tend to prevent, floods. The comprehensive word is "control," with a logical subdivision into measures for flood forecast or warning, measures of prevention, and measures of protection. The distinction between prevention and protection is well brought out in the report of the Pittsburgh Flood Commission.

On page 2772,‡ under "Suggested Methods", Subdivision (*a*), on the first line, should not "rainfall" be "run-off"? Man cannot reduce "extreme variations in rainfall", as the Committee correctly states in the last paragraph on this page, but he may reduce extreme variations in the results of rainfall.

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* Discussion of Progress Report of the Special Committee on Floods and Flood Prevention for 1915, continued from April, 1916, *Proceedings*.

† Seattle, Wash.

‡ *Proceedings*, Am. Soc. C. E., for December, 1915.

Mr. Chittenden.

Would it not be well for the Committee to recommend the definite adoption of one or the other of the equivalent terms, "drainage area", and "water-shed". The term water-shed was formerly used, and occasionally is still used, to signifiy "divide"; but its use is now almost universally confined to a designation of the territory drained by the particular stream under consideration. Probably no confusion results from the use of both terms, but simplicity of terminology is always desirable. The writer favors the term water-shed.

Several designations have been applied recently to the comparatively novel system of flood prevention which is the distinguishing feature of the great flood-control project being worked up by the Miami Conservancy District. These include "dry reservoirs", "detention reservoirs", "detention basins", and "retarding basins". When the writer was preparing his paper on Flood Control for the recent International Engineering Congress in San Francisco, he gave this matter some little consideration. Inasmuch as reservoirs may properly be classed in two distinct types, dependent on their purpose and functioning—those designed to store water for future use, and those designed to detain it temporarily for flood prevention only—it seemed wholly logical to use "reservoir" (Latin, *re serrare*, to hold back) as the generic term, so to speak, and "storage" and "detention" as specific designations. It was for this reason that he felt particular about adopting "reservoir" as against "basin". The Miami Conservancy District has definitely adopted "retarding basin", and the prominence of this example ought, perhaps, to settle the question.

Effect of Human Occupancy of Soil.—The writer feels that the Committee might advantageously have been more definite and positive in its discussion of this subject, particularly as it relates to the value of reforestation. For reasons stated later, a definite pronouncement on this subject by a professional body like this Society would have a most important influence. Doubtless, there is some reluctance to assume a positive attitude on a question which, as Mr. Knowles says, is "one of the most controversial subjects upon which engineering and scientific minds have been recently engaged." It may be questioned, however, whether to-day there is much controversy among well-informed engineers as to the essential principles involved. Is not the consensus of professional opinion that, in times of excessive rainfall, in which really great floods always originate, the restraining effect of forest cover, whatever it may be in ordinary storms, becomes exhausted and is of no effect? This is the official opinion in France, even in forestry circles, as is shown by the following extract from a report by the Director of the French Forestry Service on the 1910 flood of the Seine:

"In the exceptional circumstances which always produce the floods of the Seine, the action of forests, whether evergreen or deciduous, becomes for the moment negligible in its effect on the volume of water carried by the river."* Mr. Chittenden.

Engineers are apparently agreed on this essential point. In formulating plans for flood control, they would not dare to reduce in any degree the effectiveness of direct measures, such as reservoirs, levees, etc., by any possible measures of reforestation. The Committee brings out this point in the first paragraph of page 2777 of its report, but it weakens its position by holding out the questionable hope, implied in the words "not at present susceptible", etc., that the future may demonstrate a value in forest cover not at present apparent. Mr. Knowles, on page 2784, is outspoken in the expectation that "quantitative analysis" of the effects of forests on run-off is a possibility of the future. The writer dissents wholly from that opinion. The difficulties in the way of any such result are practically insuperable. A determination for one situation, or season, or storm, would never apply reliably to any other. The modifying influences are infinite in detail, and the utmost that we can hope for is a gross integration of results, as shown in the records of stream flow. This has already been carried on in Europe for more than a hundred years, with a wholly negative result so far as the favorable influence of forests in reducing run-off is concerned. It seems very desirable, therefore, that a report of this character should not hold out any false encouragement.

At this point, it may be well to consider a feature of the subject not mentioned in the report, yet a most important one, and one concerning which there may be differences of opinion, even among engineers. Reference is made to the influence of drainage on flood run-off. The obvious and plausible inference is that drainage—roads, pavements, sewerage, farm ditches, tile drains, etc.—expedites the run-off and fills up the streams more rapidly than formerly; but there are very strong counter forces which operate to retard run-off, particularly from originally wet and marshy soil and from swamp areas. This is the creation of ground storage where none existed before. The very purpose of drainage is to get water out of the ground; but when so gotten out, space is left for other water. The most effective and instantaneous of all reservoirs, so far as flood control is concerned, is the top 18 in. of soil, depending on the extent to which it is saturated. A swamp soil undrained is generally thoroughly saturated. It comes next to an actual body of water in that respect. The only, or the main, storage available is surface storage due to the conformation of

* "Mais, dans les circonstances exceptionelles dans lesquelles se produisent toujours les crues de la Seine, l'action des forêts, fussent-elles résineuses ou feuillées, devient momentanément négligible sur les volumes des eaux roulées par le fleuve. Les pluies intenses et persistantes de la seconde quinzaine de janvier dernier, ayant saturé le sol forestier, commes les autres terraius, les eaux tombées à la surface sont toutes allées aux thalwegs." M. Daubrée, Conseilleur d'Etat, Directeur Général des Eaux et Forêts. Report of First Commission on Flood of 1910 in the Seine, p. 515.

Mr. Chittenden.

the basin. Drainage takes the water out of the swamp soil and creates vast storage space where before none existed. This effect is fully recognized by the French. It is, of course, greatest with summer or early fall storms. Like all surface storage, it may become greatly reduced or completely exhausted by the long rains of winter.

With the utmost that can be done in attempting to evaluate the influences of man's occupancy of the soil in modifying the effects of soil cover and absorption, we find it impossible to say on which side the balance lies. It is probably not important, either one way or the other, and, in any event, becomes wholly obliterated in those excessive rainfalls which alone produce great floods. This conclusion harmonizes both with theory and stream-flow records, and should be accepted as definite and final. The writer emphasizes it, not because the popular view to the contrary influences the engineer to any great extent, but because it does influence the legislator to whom the engineer often has to look for funds, and it thus, in the words of the income tax law, "deducts" from his power of effective action "at the source". How great is the importance of taking a definite stand on this question may be judged when a distinguished United States Senator, who pretends to some acquaintance with these subjects, and whose opinions carry weight in legislation concerning them, is capable of delivering, in apparent soberness and good faith, an utterance like the following:

"We have been destroying our forests, great natural reservoirs of moisture into which the waters fall from the heavens, and where they are stored in the leaves and in the loose soil, and drunk up by the thirsty roots of the trees and vegetation, and thence the surplus gradually makes its way to the creeks and tributaries of our rivers, and the water which used to be absorbed by these forests is now hurried on into the creeks and rivers."*

If the clearing and drainage of the soil—in general terms, cultivation—do not materially affect the development and intensity of great floods, is there any respect in which man's work does enhance their destructiveness? This question admits of a definite answer in the affirmative. By obstructing Nature's overflow channels Man draws on himself the chief calamities which floods produce. The bottom

* Hon. Francis G. Newlands, in the United States Senate, Feb. 21st, 1916. It is interesting to apply this to a particular case. In the country around Dayton, Ohio, in March, 1913, after heavy winter rains had quenched to satiety any thirst from which tree or other roots might have been suffering, there fell, in a period of 3 consecutive days, between 9 and 10 in. of rain, or more than one-fourth of the average for an entire year. Assuming that the virgin forest had still covered the country, what percentage of this deluge does Senator Newlands imagine would have been "drunk up by the thirsty roots?" And what is Senator Newlands' warrant for calling the soil of the forest "loose"? Has he ever noted a great tree which has been overturned by the wind and has carried up with its roots perhaps 100 sq. ft. of soil so densely compacted that it resists for years exposure to the elements? The truth is that virgin forest soil, undisturbed for ages, is one of the most compact of soils, whereas cultivated soil, ploughed and harrowed and worked over, and full of perennially decaying roots, has the maximum absorptive capacity of which a given quality of soil is susceptible.

lands along streams are just as much a part of Nature's highway for carrying run-off to the sea as the normal channels between banks. They do not come into play so continuously, but they are a part of the natural waterways, and were formerly so used whenever the discharge rose above a certain volume. Man has pre-empted these channels entirely. They contain the most fertile lands, they are easiest to build on, and most convenient for roads and railroads. It is here that population multiplies and wealth accumulates, and whenever Nature asserts her old prerogative of passing her floods down over them, trouble ensues. By cutting off these bottoms, greater work is forced on the ordinary channel, the flood heights are raised, and if once the waters break their bounds, they not only find wealth and people in their way, but are actually far more destructive than in their natural state. Thus Man is, to a large extent, the author of his own misfortunes in the matter of flood destructiveness. The point here emphasized, however, is that Man's interference with natural conditions, which so often leads to disaster, relates to his trespass on overflow channels rather than, as is popularly assumed, on the normal channels of the streams themselves. Contrary to general opinion, Man's operations have, on the whole, improved the natural carrying capacity of streams. There are exceptions, of course, but the rule seems to be as just stated. A striking example is furnished by the recent studies of the Great Miami River, in Ohio. In the four principal towns, where channel changes have been most important, the discharge capacity was found to be from two to eight times as great as in the country above and below, where Man's interference has been slight. Such a condition, of course, cannot be accidental. Mr. Chittenden.

The foregoing remarks disclose the reason why flood destructiveness is increasing. It is not because floods themselves are increasing, either in frequency or intensity, but because property subject to destruction is very greatly increasing, and as yet protective work does not keep pace with this increase. In time, this disparity will disappear, or rather be reversed, and flood destructiveness will then show a decrease. Some railroads have already carried protective measures so far that they suffer little, even from the greatest floods.

Reservoirs.—The divergence of view between the Majority and Minority Reports, concerning the conflict of purpose of reservoirs and the impracticability of utilizing the same reservoir simultaneously for flood control and other uses, is probably more apparent than real. It would seem that the essential principles are too clear to be capable of dual interpretation. In the first place, the conflict of purpose in reservoirs can be completely overcome by giving the reservoir excess of capacity over storage requirements sufficient to provide for flood control. This, however, is often impossible for lack of site (ignoring, for the present, considerations of cost), and inasmuch as industrial

Mr. Chittenden. use, municipal supply, etc., must be on a dependable basis, it follows that they must receive first consideration. Subject to this restriction, however, storage reservoirs, as such, will generally be useful in flood prevention. It may happen that a flood-producing storm may come early, when a reservoir is filling, in which case the reservoir might be as effective as if designed for flood control only. Again, the flood storms may arrive late, after the reservoir has become full or nearly so. In that case, the discharge must go over the spillway; but as some elevation of surface is necessary to produce the spillway overflow, and as the surface of the reservoir, and the storage per unit of rise, are at a maximum at this stage, there will be, even in this extreme case, a certain degree of control.

Nevertheless, the general principle laid down in the report holds. The engineer charged with a project of flood control, in which the use of a storage reservoir is contemplated, cannot take into consideration possible advantages which may or may not accrue. If there is a possibility that they may not accrue, he is bound to assume that they will not. He must make the most unfavorable assumption within reasonable probabilities. Having thus determined what aid can be positively depended on from the reservoir, he must make other provisions for such additional control as is required. It is right here, it seems to the writer, that public supervision of reservoir construction is demanded, and that public aid in the interests of flood control might well be given. For example, if a reservoir site is about to be developed on a stream where the flood problem is important, it might well be that, by increasing the capacity beyond what would be sufficient for storage purposes, the reservoir could also be made to serve the additional purpose of flood prevention. In that case, public aid would seem to be justifiable.

On the whole, the possibilities of combining flood prevention with other uses of reservoirs are sufficient to justify Mr. Knowles' contention that the Committee's report would be strengthened by omitting lines 7 and 8 on page 2778*: "Your Committee, however, does not intend to condemn *in toto* the utilization of reservoirs for more than one purpose."

Barriers.—The comment on "Barriers", (*c*) page 2778,* seems to the writer most judicious in recognizing only the function of arresting débris. Just now there is current another of those extremist propagandas which have interfered so much with scientific treatment of many of our problems by confusing the public mind with schemes the only virtue of which is superficial plausibility. Los Angeles, Cal., is the present victim. A campaign is on there to make barriers the sole, or at least principal, solution of the flood problem in that locality. There has been created a "very wide-spread furore that the only way to control the flood waters [at Los Angeles] is to build myriads of little

* *Proceedings*, Am. Soc. C. E., for December, 1915.

check dams in the mountains, and, through the detritus caught above each of them acting as a sponge, to soak up all the floods before they leave the mountains." Mr. Chittenden.

So far as the writer has observed in reports on this subject, the primary purpose of these check dams is to prevent erosion. Not much stress is laid on their effect in storing water. They soon become filled with detritus, and this, in the general case, will become well soaked with the rains leading up to great flood storms, so that the chances in favor of any material reduction in discharge are altogether uncertain. Immediately following a dry spell, a heavy run-off might be considerably reduced, whereas, with a storm of the same intensity following a series of lesser rains, there might be practically no relief. In this, as in the case of forests, the engineer cannot build on uncertainties.

Outlets.—With some hesitation the writer offers a certain criticism of the conclusion stated in Paragraph 4, on page 2780.* So far as he has followed the official reports on the subject, it is evident that there is an important distinction between the outlets proposed, say, near New Orleans, and natural outlets or accidental crevasses cited as militating against the outlet theory. It is manifest that the action on the regimen of a river of a great crevasse must be different from that of a long overflow weir which comes into play only after the river has reached a certain stage. The writer cannot understand why, if the river safely transports its sediment at that stage, it should fail to do so by preventing any marked rise thereafter through abstraction of the surface flow by a weir. It is very possible that the outlet channel itself might silt up and become ineffective, but that would have nothing to do with the argument just advanced.

Cut-Offs.—Having now reviewed the general features of the report, the writer desires to devote more detailed consideration to the subject of cut-offs. In general, his views coincide with those of Mr. Grunsky. He believes that the ultimate effect of cut-offs is beneficial, providing always that those reasonable and obvious precautions are taken which the circumstances of the individual case clearly indicate. He dissents from the orthodox view, so long held on the Mississippi, that that river has a sort of intelligent purpose in maintaining a particular length of channel, and that it always "seeks" to regain that length if suddenly shortened by the excision of a bend. The truth is that a river in an alluvial soil may perform almost any antics which the physical conditions will permit; but, that such a river has a definite length which it is always seeking to maintain, is an assumption not substantiated by fact, at least on other streams.

In illustration of this point, the writer presents a diagram (Fig. 3), showing the changes of a century in about a 50-mile course of the

* *Proceedings*, Am. Soc. C. E., for December, 1915.

Mr. Chittenden.

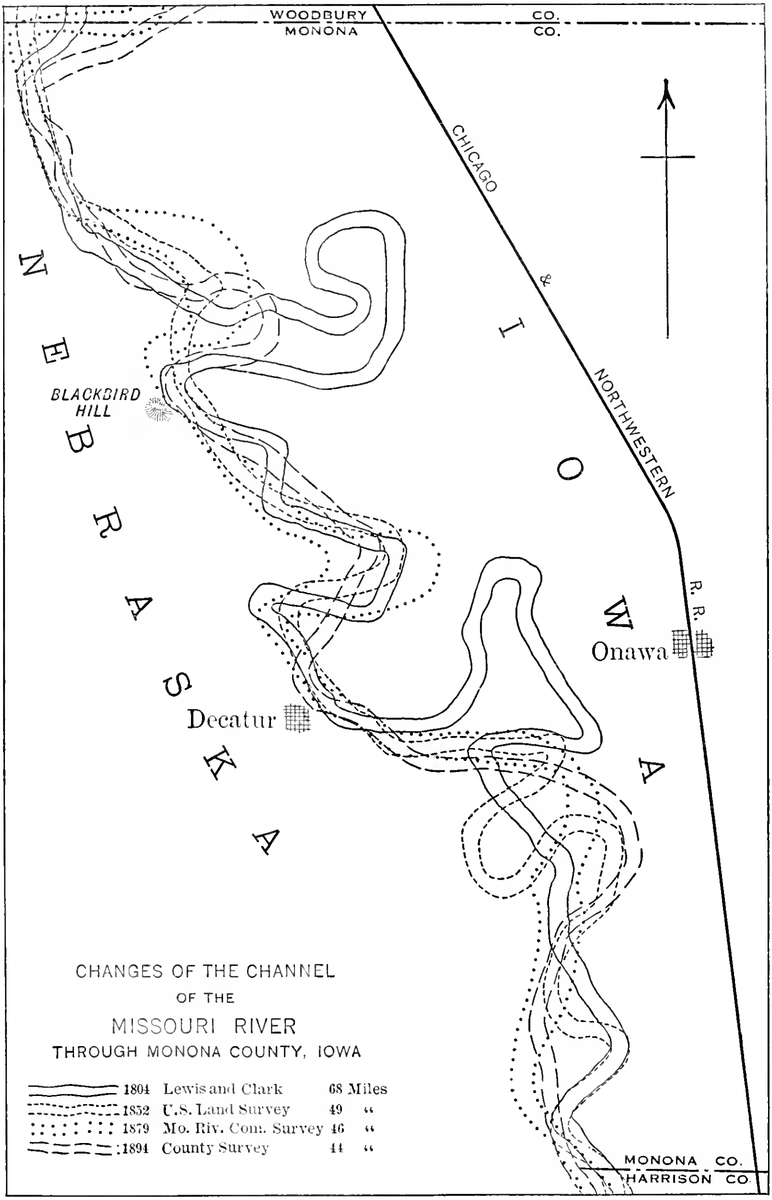

FIG. 3.

Mr. Chittenden.

Missouri River. The early cut-off of some of the enormous bends that existed in 1804 has never resulted in any "attempt" on the part of the river, either on this section or above or below, to regain its original length. On the other hand, successive surveys show if anything a contrary tendency; and there is nothing in the long record of navigation on that stream which indicates any ill results to navigation resulting from such cut-offs.*

The writer also questions the correctness of the statement that cut-offs "increase flood heights below them", while "reducing flood heights immediately above". This may be the first effect, but it is not first effects, but permanent results, which must be considered. In the long run, the result, according to the writer's observation, is to draw down the channel above the cut-off until it comes practically to the original grade of the channel below. (It is understood that we are here considering only the case of alluvial streams in comparatively unstable channels.) In the course of time, these effects may extend many miles up stream, and the sharp change of slope at first produced may be distributed so far as to be very slight per unit of distance.

Fig. 4 is reproduced from a photograph of quite an extensive cut-off on the Missouri River which took place under the writer's observation.

The channel shortening, as he now recalls (without verification from the records), was about 7 miles. Much local alarm was felt lest the cut-off should produce a flood below. The writer tried to assure the public that no such thing could possibly happen; that the cut-off in itself would not increase the discharge of the river at all, except as to the small increment from draining the bend, and that there was absolutely no danger. Nothing would allay the fear, however, and there was much talk of taking steps to prevent the cut-off, when certain interests which wanted it to take place rendered judicious assistance (with dynamite, mainly, it was said), and the controversy was promptly settled. At the first gauge below, a rise of a few inches was detected, but no untoward result whatever happened. In this case, the writer feels certain that the final result was a lowering of the old bed above the cut and not a raising of the bed below.

The reports of the Mississippi River Commission abound in references to work designed to prevent cut-offs which might (to cite a particular case) "disturb the regimen of the river a long distance above and below, and bring disaster to towns, levees, and other works along the river banks." The results of a cut-off that did take place are traced in considerable detail, showing how one ill effect led to another,

* One naturally questions the correctness of the early maps on which these extreme bends are shown; but, apart from the general accuracy of Lewis and Clark's work, as shown by later surveys, there are authentic references in the journals of other early voyages up the river. It never took less than a day and sometimes two days for a keelboat to get well past Blackbird Hill, opposite the neck of one of these bends, after having arrived in its vicinity.

Mr. Chittenden. until a heavy toll of misfortune had accumulated. All this appeals to the writer, however, as a clear case for the Franklinian philosophy contained in the parable of the horse-shoe nail. If the occurrence of this cut-off had been anticipated by timely protective work above and below, probably nearly all the ill effects which actually developed might have been avoided. The writer would not for a moment criticize official policy in preventing cut-offs on the Mississippi River; he simply criticizes the theory on which that policy is ostensibly based. He believes that the real objection to cut-offs on that stream is not the effect on the regimen of the river (which can be controlled effectively), but on riparian interests. Ports and landings might be ruined and other interests jeopardized in a way that would result in serious hardship; but, aside from these considerations, viewed only as a problem in river hydraulics, the writer believes that a material shortening (say 125 to 150 miles) of the Mississippi River between Cairo and Red River would not, in the long run, injure the regimen, even for purposes of navigation, and it would certainly make the river a better flood carrier and would reduce materially the length of channel to be maintained and of bank to be protected.

The writer would dissent, further, from the distinction which the Committee draws as against alluvial streams in this connection. It is, in many instances, on alluvial streams that this measure can be best applied. The difference between an alluvial stream and one with stable banks is that, in one case, disturbance of regimen may result, and, in the other, it may not, and that, therefore, in using the cut-off on alluvial streams, auxiliary measures are necessary. If these are provided, however, the shortening of the channel should certainly facilitate the natural movement of sediment down stream. Cut-offs have been used extensively on great alluvial rivers, notably on the Danube and other streams of the Hungarian plain.

The cut-off method finds its most effective application in low flat tracts in which stream sinuosity dates from the remote period of emergence of the soil from a status of continuous overflow, and is not a result of present-day processes. Generally, in such locations, the sinuosity is excessive, the slope very slight, and the channel capacity wholly deficient. Extensive cut-offs do not produce excessive slopes and troublesome erosion, but facilitate drainage and carry off flood waters more rapidly. Whether in any particular case a cut-off or series of cut-offs is desirable depends on local circumstances. The most important obstacles are cost and the likelihood of riparian complications. Another consideration relates to the excised portions of the channel. If these can be filled up, there is a net gain of land area, for the excised portion is always larger than the new channel. If they cannot be filled, there is a loss of land equal to the new channel. Even in that case, there may be some utility in the excised sections in

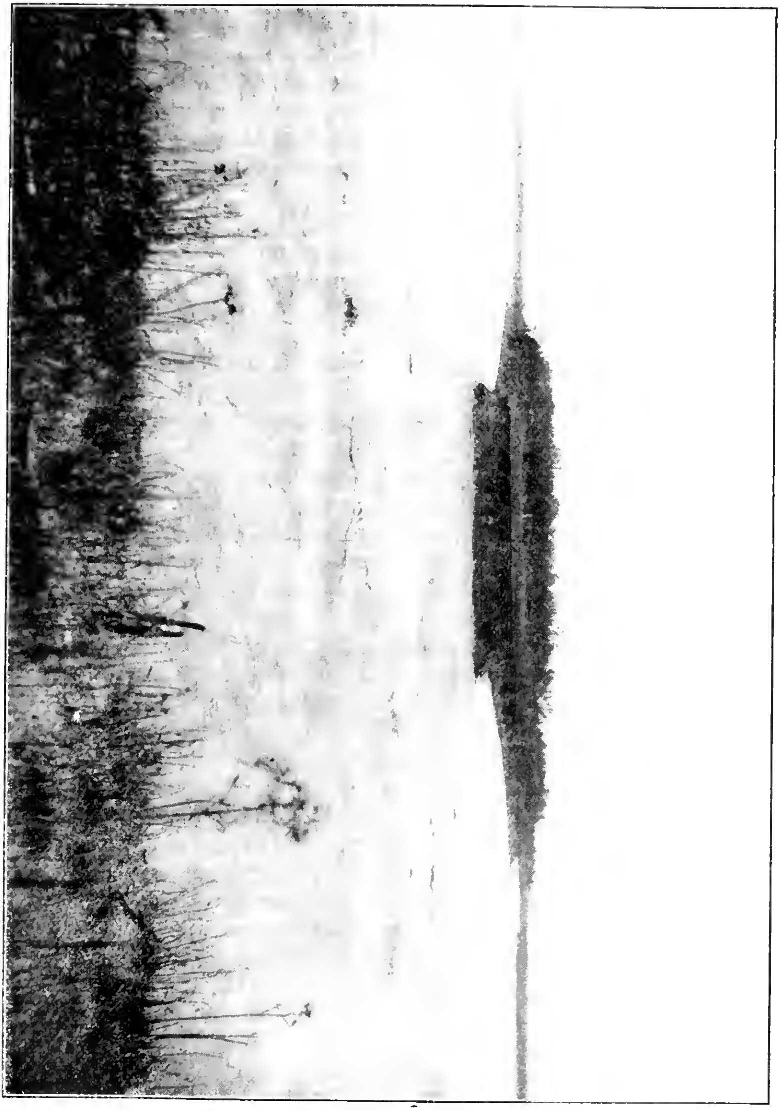

FIG. 1.—A NEWLY FORMED CUT-OFF ON THE MISSOURI RIVER. OLD CHANNEL IS TOWARD BACKGROUND ON THE LEFT AND FROM BACKGROUND ON THE RIGHT.

connection with drainage. By placing flood-gates between them and the new channel, they can be drawn down to the level of low water in the dry season and then be utilized as immense sumps to maintain effective drainage during high-water periods. Mr. Chittenden.

Minority Report.—Concerning the several substitutes proposed in the Minority Report, some of them seem to be in the interest of completeness and precision, and some appear to the writer as undesirable. Among the latter are the proposed changes in the forestry discussion. As to (10), on page 2786,* it would seem that Mr. Knowles confuses two distinct things. The fact that levees cut off valley storage previously available does not in any way alter the other fact that levees, by raising the flood surface between them, do develop a certain amount of channel storage.

It is important, however, to observe a distinction, which neither the Committee nor Mr. Knowles has brought out, but which justifies to some extent Mr. Knowles' contention that "such storage is ineffective", although for a reason quite different from that which he has assigned. It is entirely true that the volume of water at flood stage stored in stream channels, like the Mississippi and Ohio, is prodigious, including as it does not only storage in the channel proper but the filling of side ravines and tributary valleys and the overflowing of bottom lands back to high ground or levees. The natural impulse is to give such storage great weight in holding down flood heights; but this is clearly inadmissible. Channel storage is mainly absorbed in the preliminary stages of a flood. The case is similar to that of a reservoir which has been filled from the earlier rains and has no space left for the later rains; and though it may still exercise a slight moderating effect on run-off passing through it, such effect is not at all in proportion to the full capacity of the reservoir; and the more prolonged the crest of the flood is, the less will be even this attenuated effect.

The same conclusion may be reached by a hypothetical illustration. Suppose the Ohio River from Pittsburgh to Cairo to be a closed conduit, of cross-section equal to, say, the ordinary low-water section of the open channel; and suppose that, by some mechanical process, sufficient velocity could be imparted to the current in the conduit to carry away all run-off as fast as it should present itself. It is manifest that the discharge at Cario during rising stages would be greater than with an open channel, due to the fact that no storage had been allowed to accumulate; but this difference would evidently disappear when the maximum stage had been reached and there was no further accumulation of storage. At the critical point of the flood, therefore, the reservoir function of the channel ceases to have effect.

The writer feels the more freedom in criticizing the Committee's treatment of this matter because he is at the same time criticizing his

* *Proceedings*, Am. Soc. C. E., for December, 1915.

Mr. Chittenden. own previous utterances on the same subject.* The conditions are abstruse and difficult to lay hold of definitely, but the writer believes that they are fairly set forth in the following statement:

Storage in and adjacent to the channel of a stream, which results automatically from an increase of stage, has little if any effect in reducing the maximum stage. It operates to reduce somewhat the rates of discharge during rising stages while storage is actively accumulating, but this effect gradually disappears on approaching the maximum stage where storage accumulation ceases.

Mr. Fuller. MYRON L. FULLER,† ESQ. (by letter).—The problem which most nearly attains successful solution, whether it be one of business, science, or engineering, is that which takes into account, duly analyzes, and gives proper weight to the greatest number of contributory factors.

Of the factors of flood control or prevention, geology is assuredly one that must be reckoned with. The far-sightedness which is essential to the satisfactory conclusion of any great undertaking demands that every known factor of the problem be considered and the weight given to it that mature investigation shows it has the right to claim.

Nothing is more true than the following statement‡ by Morris Knowles, M. Am. Soc. C. E., in the Minority Report of the Special Committee. "It is unwise to assume that we have at any time obtained all the knowledge possible upon a given subject." Every year sees new advances in our knowledge of engineering problems; and our ideas as to the precautions necessary in engineering undertakings are continually changing. Factors hitherto unknown or neglected are almost daily found to be of importance.

Most of the great failures in engineering works, as well as in other lines of business, have been due directly or indirectly to overlooking some inconspicuous factor or neglecting some element of apparent insignificance. For example, the lack of knowledge as to the weakness and slipping planes in shales, or the failure to realize their significance, has resulted in the failure of several large dams and reservoirs within the past few years, and the inadvertent omission of some engineering factor has played an important part in the collapse of bridges and other steel structures.

The writer does not maintain for a moment that the success or failure of flood prevention or control measures is dependent on geological investigations, but he does contend that geology is one of the factors—sometimes one of marked importance—which should be considered in any comprehensive investigation looking to the prevention or control of floods.

* "Flood Control, with Particular Reference to Conditions in the United States", presented to the International Engineering Congress, San Francisco, September, 1915, pp. 16 and 22.

† Boston, Mass.

‡ *Proceedings*, Am. Soc. C. E., for December, 1915, p. 2783.

Insufficiency of Precipitation Data.

Mr. Fuller.

Notwithstanding the great efficiency of the Weather Bureau, rainfall data, chiefly because of the comparatively short periods during which records have been kept, are admittedly insufficient for the determination of the maximum possible or even probable precipitation in a given area.

It is true that a certain approximation to the probable maximum precipitation may be made from an inspection of the rainfall records throughout the general province or climatological zone of which a given district is a part, by applying the maximum precipitation recorded elsewhere to the area under consideration. As is well said in the Progress Report of the Special Committee (page 2773*), however, "it is improbable that the maximum precipitation that may occur at a given locality has yet been recorded."

Taking the maximum rainfall recorded for the province or zone, and the maximum known accumulation of snow for the same latitude and altitude within the zone, it is possible to estimate the probable height of a flood under existing conditions of channel. The height calculated, however, is by no means free from likelihood of error, and it is entirely possible for the water to rise many feet higher than the estimated limits.

Geological Clues to Flood Heights.

Flood-Plains and Terraces.—In the absence of sufficient rainfall data, it is fortunate that geology furnishes, in many instances, a clue to the probable heights of flood-waters. The clue referred to is that afforded by the flood-plains and terraces, which often give evidences of heights of water greater than those which would be indicated by the computations from greatest recorded rainfall.

Generally speaking, there is little evidence that floods are either more or less pronounced and frequent at the present time than in the immediate past. This, of course, does not apply to the more remote geological past, when climatological conditions were radically different.

The evidence afforded by flood-plains is not altogether simple or universally present. Mountain streams, having steep gradients, are usually cutting rather than depositing, and flood-plains and terraces are commonly absent, although even in mountainous regions elevated pockets of sand often afford clues to the high-water limits. In flatter regions, such as the greater portions of the Mississippi and Ohio Basins, the streams are generally aggrading or filling their valleys, at least locally, and are commonly bordered by flood-plains or terraces.

* *Proceedings*, Am. Soc. C. E., for December, 1915.

Mr. Fuller. The flood-plains are fundamentally constructional in origin, being built up of the relatively fine deposits laid down when the waters of the streams overflow the normal channels and spread out with checked velocity. The upbuilding continues, unless new geological or artificial factors intervene, until the surface reaches nearly the level of the highest floods. During the later stages, the upbuilding is very slow, and the floods overtop the flood-plains only at long intervals, perhaps of centuries. In the majority of localities the flood-plains have not reached their final stages, especially where, because of constrictions of the channels or other causes, the currents are unusually swift, but are still overflowed to a depth of several feet by the greater floods.

The uncompleted stages of the flood-plains introduce large elements of uncertainty, and the problem is still further complicated by the fact that portions of the once completed flood-plains may have been subsequently eroded away, leaving surfaces much lower that the levels reached by the floods. In other words, a series of terraces is left, only the uppermost members of which are of significance in determining flood heights.

If this was all, the problem would still be comparatively simple, but further difficulties are introduced by the fact that, in some instances, the whole river valley has been cut in glacial or other sands and gravels of a past geological period. In this down-cutting, terraces similar in appearance to those of the flood-plains are commonly left at various levels.

The determination of which of the general series of terraces in a given valley are due to upbuilding, and are, therefore, of significance in the determination of probable flood levels, and which are due to down-cutting, and are without present significance, is often difficult, and the discrimination can seldom be left to the engineer with safety, or even to the academic geologist of the average college faculty. The discrimination can be made, but it requires a practical and experieneed field geologist to make it with certainty.

The flood-plains and terraces, notwithstanding their complexities, afford a line of evidence that should not be neglected in any comprehensive investigation of flood control. When the writer was engaged in Ohio on Government geological surveys, ten years ago, the question was several times asked in regard to towns or their water supplies: "Is there any danger from floods?" The answer was that the towns were situated on flood-plains built up by repeated overflows of the streams, and that similar overflows were bound to occur in the future unless artificially prevented. The writer did not necessarily expect a flood of the proportions of that of 1913 so soon, but it was bound to come eventually.

Geological Obstructions to Streams.

Mr. Fuller.

Geological obstructions to streams, because of their obscurity, are often overlooked—or their importance under-estimated—in flood-control studies. Two distinct types may be mentioned: the boulder delta and the rock barrier.

Boulder Delta.—Existing deltas or fans of boulders or coarse gravel are manifest obstructions, and are recognized by engineers as such. They occur chiefly where side streams having steep gradients issue from hills or mountains into broader valleys where the streams are more sluggish and are usually engaged in building up their flood-plains. Often, the main streams are pushed aside and forced close against the opposite banks, where they flow in comparatively narrow and deep channels. They are obstructions which have an unmistakable and calculable effect on flood height.

The deltas which are not pre-existing, on the other hand, introduce important but unknown factors. A severe rain over the water-shed of a small tributary is felt almost at once, and the stream commonly responds long before the water rises very materially in the main valley. The result is that enormous volumes of material are often swept into a river, causing great accumulations of gravel or boulders where no deposits may have previously existed. It is true that, as the main river rises, many of these accumulations may be swept away, but, in the meanwhile, they are a very real obstruction, with an important influence on flood heights. Their final destruction may inaugurate flood crests endangering the whole country below. Under other conditions, the deposits may become permanent features, at least for a considerable period of years.

The boulder or gravel deltas of this type are certainly worthy of attention in flood-control studies, and geological investigations of their possible effects are highly desirable.

Rock Barriers.—In many of the valleys in the Ohio and Mississippi Basins there are buried rock channels much deeper than the general rock floors over which the streams now flow. The latter commonly mark the depth to which the scour of the river extends during flood periods at the present time; the deeper channels mark the former positions of the river under different conditions of level or discharge. Sometimes, the present channels coincide with the older rock gorges, in which case the scour may extend to somewhat greater depths. Sooner or later, however, the streams have to return to the general rock floors, usually accompanied by sudden rises in the bottoms. This has an important effect in checking flow and in promoting deposition.

Although the importance of the rock barrier is less than that of the delta, its influence is sufficient to warrant taking it into account in the flood-control problem.

Mr. Fuller.

Geological Factors of Run-Off.

The principal geological factors of run-off are: the grain of the soil, the thickness of the soil, and the nature of the underlying rock, including composition and fissuring.

Grain of Soils.—The grain of soils, using the term "grain" in its broader sense to include the arrangement and packing of the particles as well as their size, is of the greatest importance in run-off and flood studies of a given water-shed. A proper study of the grain includes both laboratory tests and field examinations. The former consist of sizing tests or analyses by passing the material through a series of standard screens of various meshes, and from them may be computed the rate of percolation under different conditions. Direct tests on blocks of soil cut from the ground, where the material is sufficiently firm to hold together, have been found, in the writer's experience, to afford still more dependable results. All measurements or estimates of rates of percolation apply, naturally, only to unfrozen soils, hence are of value only in seasons where the ground is free from frost.

Classification of Soils.—Accompanying the percolation estimates and tests mentioned—which are as much of an engineering as of a geological nature—field examinations must be made, and the soils classified, mapped, and their areas determined. These can be made best by a geologist or soil expert. Samples, at the best, can be taken at only a limited number of points, and must be supplemented by a soil classification of the entire area, if the work is to have any real value. The geologist's knowledge of the general character of residual soils, or those resulting from the weathering of different types of rock, of the nature of the various classes of glacial deposits, and of the composition of the alluvial accumulations, is of the greatest assistance in this branch of subsidiary investigations in flood-control studies.

Depth of Soil.—The depth of soil is of much greater significance than is commonly realized. The writer's ground-water studies in some thirty States have shown that rocks free from soil coverings seldom contain much water, and that the same rocks, when covered by a thick soil mantle, afford abundant supplies. Conversely, when the soil is thin, the immediate run-off is much greater than where it is thick. Therefore, geological studies to determine the depth of soil are of considerable importance in run-off studies.

Composition of Rock.—The absorptive capacity of the underlying rock is a factor of significance in flood control. The porosity or absorptive capacity varies greatly in rocks of different classes, ranging from $\frac{1}{2}\%$ or less in quartzites to 5% in shales and limestones, and 25% or more in sandstones. Many engineers can recognize the various major varieties of rock, but the numerous errors in determination which are indicated by the reading of engineering literature show that it would be far safer to rely on a geologist than to leave rock determinations to guesswork. Mr. Fuller.

Fissuring of Rocks.—Fissures in rocks have been mentioned by several engineers as a factor in natural flood regulation. Broadly speaking, rock fissures are of four general types: cleavage planes, bedding planes, joints, faults, or other fracture planes, and solution passages.

The cleavage planes, limited chiefly to slates, and the bedding planes of sedimentary rocks, are commonly potential rather than actual fissures, and, even when open sufficiently to admit water, take it up and deliver it very slowly. They affect the flood heights but little, their office being that of feeders and regulators of low-water flows.

The openings along joint or fault planes are rarely more than a fraction of an inch in diameter, and although of more importance than cleavage and bedding planes, they are likewise regulators of groundwater flows in low-water stages, rather than factors in floods.

The solution passages in limestones, on the other hand, are often many feet in diameter. The Mammoth Cave of Kentucky, with its large passages several miles in length, is an example of this type. It is now abandoned by the stream that formed it, but, elsewhere, similar channels are still occupied by underground rivers. The writer has seen such a stream on the outskirts of the Ozarks, in Missouri, where a torrent several feet in width and a foot or more in depth rushed along underground with rapids and falls like those of a surface stream.

Such solution passages are natural tunnels capable of carrying immense volumes of water. Nevertheless, notwithstanding their frequency and large capacity, they are rarely elements of importance in floods, as they replace rather than supplement the normal surface drainage. Practically all of them are above the normal drainage levels of the main streams, or those in which floods are likely to occur, and lead from limestone sink-holes or other openings in the hills down to the main valleys which determine the levels of their outlets. Although they can lead water down to a flooded stream, they can seldom, in the absence of lower outlets, take it away.

If clogged, a certain quantity of water is sometimes held back, but this is often compensated by the breaking loose of obstructions previously formed in other passages, and the setting free of waters to be added to the flood.

It is to be noted, however, that in a few localities streams of considerable size are known to flow at heights of several hundred feet above adjacent streams. If in a limestone region, a solution passage might take away a large proportion, if not the entire volume, of the

Mr. Fuller. higher stream, but the quantity taken from the upper stream would be added to that of the lower, where the flood conditions might be even more serious.

It is apparent, therefore, that solution passages may be a real factor in floods, and, though not a common element, are sufficiently frequent to demand recognition. In storage reservoirs, where the water is held above both the normal drainage and ground-water levels, they are often of paramount importance, and great precautions are necessary to prevent damage or loss through their agency. The reservoir failure at Johnson City, Tenn., on January 10th, 1913, is an example of failure from neglect of solution passages.

Geological Factors of Ground-Storage.

The storage capacity of the sands and gravels of alluvial deposits adjoining a stream is a factor of considerable importance in flood regulation. The pore spaces of such materials commonly range from 25 to 35% of their volume, and although the residual moisture already present may reduce this very materially, there is usually an available porosity of from 10 to 25 per cent. In other words, 10 ft. of gravel will take up the equivalent of from 1 to 2½ ft. of water. Of course, if the rise of the flood is slow, the gravels will often fill with ground-waters from the hills, but, in sudden floods, the ground-waters have insufficient time to respond to change of level, and adjacent sands and gravels will become filled from the river. The inflow into the gravels is often quite rapid. In one case observed by the writer a cellar 100 ft. from a stream subject to sudden fluctuations was filled to stream level with a lag of less than 2 hours.

It is apparent, therefore, that under favorable conditions, the storage capacity of adjacent deposits may be a prominent factor in floods, and geological studies, to determine their location, extent, and availability, are highly desirable. In such studies, the aim should be to determine, in addition, the presence or absence of buried rock masses which might limit the storage capacity of a particular formation. Buried barriers of rock opposing the free movement of the underflow and bringing it to the surface to be added to the floods should likewise be located whenever possible. The position of buried channels, if present, should be determined, for they may provide outlets for the underflow at high-water stages when not available at low stages, or may at least afford additional storage.

Limited Value of Sedimentation Basins.

Moving water will always carry its full load of sediment if the material is available. It is a geological principle that, if it does not already have such a load, a stream will pick it up from its bed or banks until it is fully loaded. The greater portion of the coarse material under transportation by a stream is carried only a short distance. It is picked up where the current is accelerated, the scour often extending to depths of 30 ft. or more, but it is deposited in large measure as soon as the current is checked. Only the finer and relatively harmless silts become a permanent addition to the water. In the course of time, by innumerable repetitions of the process described, the coarser material is carried to points far distant from its source, but very little except the finer silts is transported to any considerable distance during a single flood. Mr. Fuller.

For these reasons, it appears that, as a general rule, sedimentation basins may be expected to be of limited value, although, as local protection, they may occasionally be entirely successful.

Levees.

A levee system, by confining the current of a stream, tends to intensify the scour, and for the same reason, subsequent deposition may be hindered. In the long run, river bank erosion is reduced, and such deposition as occurs is probably less harmful than along an uncontrolled channel.

Outlets.

The value of natural or artificial outlets depends to a considerable extent on geological conditions. An outlet may present a shorter line of discharge and a straighter course than the existing channel; but, unless the water can get into it freely, it is not likely to be utilized by a stream. The inlet to it must be free from obstructions and in line with the natural swing of the current, and the banks must not cave (in proportion to the volume of water) more than those along the existing outlet.

If any considerable volume of water follows a new outlet, temporary relief is, indeed, afforded, but the improvement is not permanent. Either the new or the old channel will soon silt up, and the final condition will be no better than before. The Hwang-Ho, in East China, shifted its mouth a distance of 275 miles in 1852, but flood conditions are said to have been accentuated rather than relieved.

Necessity for More Comprehensive Studies of Streams.

The Government, in connection with its comprehensive and detailed studies of the Mississippi and its larger tributaries, has secured very complete data on erosion, transportation, and deposition by low-gradient streams, especially in their lower reaches. There is, however, a deficiency of data pertaining to the upper reaches and at the head-waters.

Mr. Fuller. It is evident that the conditions in the upper portions of most large streams are entirely different from those in the lower portions. In the latter, notwithstanding the wholesale caving of the banks, the excavation of cut-offs, etc., deposition predominates, and stream beds, flood-plains, and estuarine deposits are being gradually built up. On the middle reaches erosion and deposition are more nearly balanced, and the conditions as regards flood-control are essentially different. In the upper reaches and head-waters, erosion usually predominates, and flood conditions differ materially from those of either the lower or middle reaches.

In many of the smaller drainage basins, such as those of several of the Ohio tributaries, all three conditions are represented within comparatively short distances, and no one set of laws of erosion and deposition will apply. The data derived from the Mississippi studies may be applicable to the lower reaches of these streams, but there is a decided deficiency of information as to the behavior and work of the streams in their upper sections.

The result of this deficiency of knowledge of the behavior of the swifter streams is illustrated by the destruction of many railroads at various times in the past in the canyons of the West, especially along the San Pedro line between Los Angeles and Salt Lake City, which was rebuilt for long distances after its destruction by flood about 6 years ago.

The question of run-off needs more careful consideration, especially the effect on it of forestation, with a view of fixing quantitative values that may be depended on with more certainty than is now possible.

Flood depths and flood velocities in mountainous and hilly regions need more extended investigation in order that the limits of danger may be more definitely fixed. This is often even more important than similar investigations in the flood-plain sections, as the floods are more sudden, more uncontrollable, and more destructive than in regions of the latter type.

The size and nature of the material available for transportation are also important factors in floods. Structures that might withstand the water alone may fail under a bombardment of boulders, often hundreds and sometimes thousands of pounds in weight, which are swept along by mountain torrents. More information is also needed as to the effects of bends of various radii in the canyons and valleys, as well as the influence on floods of narrowings of the valley walls.

Many of the factors mentioned are geological in their nature, and their investigation would naturally take place in connection with that of the numerous other geological problems involved in flood regulation or control.

Final Statement.

Mr. Fuller.

A few of the geological factors entering into the problem of flood control and prevention have been stated briefly. Many others would undoubtedly develop in the field. The writer believes that some of these factors will be generally acknowledged as of unquestionable importance. At any rate, it is not safe to pass them by without mature consideration in any broad investigation of floods.

AMERICAN SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

DISCUSSION ON THE BEARING VALUE OF SOILS FOR FOUNDATIONS, ETC.*

By E. P. Goodrich, M. Am. Soc. C. E.

E. P. Goodrich,† M. Am. Soc. C. E. (by letter).—This report, with the appendix, deserves most careful study by those interested in the physics, chemistry, and engineering of soils. It is felt, however, that the report does not quite conform to the expectations on the subject, and might have been amplified to considerable advantage in many points. Not many men know exactly what is meant by, or how to measure, the limits of porosity and coagulability mentioned in Table 1. It is believed that the word "sedentary", in connection with soils derived directly from the disintegration of rock, is not a happy selection, and that some confusion is apt to arise in one's mind when "glacial" is included among the kinds of soil when classified with reference to "Processes of Formation". It would seem better to classify: first, with reference to chemical origin; second, mechanical origin; and third, method of deposit, rather than to put all under the heading, "Processes of Formation", if any such detail is deemed necessary as has been followed by the Committee in defining the water content. It is to be supposed that the unit volume used as a basis is the dry volume, although it is not explicitly stated. Mr. Goodrich.

The discussion contained in the appendix is of even more interest than the report of the Committee. The final decision arrived at by the Sub-Committee as to the design of a testing device is interesting, but would be a foregone conclusion on the part of any one who studies the question even casually. The writer concurs most heartily with the

* This is a discussion of the Progress Report, of the Special Committee to Codify Present Practice on the Bearing Value of Soils for Foundations, for 1915, presented to the Annual Meeting, January 19th, 1916.

† New York City.

Mr. Goodrich.

conclusion of the Sub-Committee concerning the assumed "central cylinder" with reference to granular earths. It is believed that the criticism of the writer's device with reference to the discontinuity (or singularity) introduced at the rim of the piston is of much less moment than will be the result of the deflection of the best possible device which depends on the action of a fairly elastic measuring membrane. Of late years, the writer has developed a device in which a solid plunger is maintained absolutely in line with the walls of the cylinder, just so much pressure being applied as will maintain this condition within a very much smaller fraction than even that secured by the Committee (0.00005 in.) in its investigation. The writer also believes that for proper work there must be a very much larger cylinder than has yet been used by any investigator, or that there must be cylinders of different sizes in order to ascertain the effect of such a variation on the elements of the problem.

MEMOIRS OF DECEASED MEMBERS

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

WILLIAM HARLIN KENNEDY, M. Am. Soc. C. E.*

DIED MARCH 14TH, 1915.

William Harlin Kennedy was born at Baltimore, Md., on June 15th, 1835. He was of Scotch-Irish ancestry of excellent record, who came to America only three generations back. His choice of a profession was not influenced by early association or environment, business interests mostly having claimed his immediate forbears. He began his work very young and almost in the infancy of railroad building, but showed such marked ability for location that, later, he took a high standing among his confreres in the carrying out of important projects.

Mr. Kennedy received his education at the Western University of Pennsylvania. On leaving that institution he at once began practical railway work, joining the surveying party of Mr. Sigismund Low on the Pittsburgh and Connellsville Railway in 1853.

In the beginning of 1857 he resigned to take the position of Assistant Engineer on a railway project in Kentucky, but financial stringency stopped the work. Another line, the Milwaukee and Beloit Railroad, gave him the responsible position of Division Engineer, but this road shared the fate of the previous one after about half a year of construction. He now took up what, in another profession, might be termed "free-lance work" and went farther West. At the beginning of 1858 he reached Kansas City, a river town with several thousand inhabitants but with little promise of its later astonishing growth. For several months he served as Assistant City Engineer under Mr. De Ham, who had been with him on the Pittsburgh and Connellsville work, and who was his valued friend. For a time Mr. Kennedy was also engaged in running meridian and standard parallel lines for the Government, and was for a time with the Kansas City and Cameron Railroad.

A reply to a letter received from his brother, James K. Kennedy, who lived in Walla Walla, during the latter's return trip from a visit to the old home in Pittsburgh, in 1871, gives some idea of the Kansas of ante-bellum days:

"Salina, the place you write from, is very familiar to me. I have shot buffalo there in 1858-59. It was laid out as a town site by a

* The data for this memoir were mostly provided by Emile Low, M. Am. Soc. C. E., and Messrs. Thomas K. Gray, J. C. Havely, Henry B. Thielson, and Charles Steele.

Scotchman, a reporter for the New York *Tribune* during the Border war—I have forgotten his name. When I was surveying in that vicinity I got all the inhabitants of Salina, one named Spielman, a brother-in-law of the proprietor, and the other a little Scotchman who had taken up a claim adjoining the town site, to go with me as chainmen, and they worked the whole season, leaving the town of Salina entirely deserted. The proprietor of Salina is the man I was telling you about when you were here, who, when attempting to catch a buffalo calf, was tossed up in the air by it and had the stock of his rifle broken off short in the fall.

"Around this town in those days and all around the plains adjoining and west and along Solomon's Fork and Grand Salina River were the hunting grounds of the Indians. Buffalo and antelope abounded in great numbers, especially the buffalo, and I have often seen the plains, as far as the eye could reach, black with them. The Indians came here in considerable numbers during the hunting season to get buffalo robes and to lay in a supply of dried meat. I believe the Pawnees claimed the grounds thereabouts, but the Kaws, the Ottawas, Kiowas, Delawares, Shawnees, Pottawattamies, Wyandottes, and a number of other tribes all hunted there, and of course some of them would fight when they met. I remember a time when we were in camp near a Pawnee camp about 40 miles beyond Salina, seeing them dance the scalp-dance around some posts which they had erected and on which were hung three scalps, some fingers, toes, and other fragments of the bodies of some Kaws whom they had that day killed in a fight. They were horribly painted and yelled like devils, and I thought at the time what a blessing it would be to the whites if all the Indians on the plains were to fight like the Kilkenny cats and with the same result."

Mr. Kennedy joined the Masonic Order while in Kansas, and took the Master Degree in Kansas City, on October 6th, 1860.

He returned to Pittsburgh in 1861 and went with the Pennsylvania Railroad as Assistant Engineer-in-Charge of Construction near Cresson. The late Alexander J. Cassatt, afterward President of the Pennsylvania System, was Rodman for Mr. Kennedy in 1861. The latter had charge of the construction of the old Union Station in Pittsburgh, which was built in 1865 and destroyed by fire during the riots of 1877. It is a peculiar circumstance that he was on the first passenger train that left the old station on its completion, and, returning from Fredericksburg, Va., was also on the last regular passenger train that ever entered it.

Mr. Kennedy was with the Pennsylvania Railroad at the time Gen. Morgan made his spectacular raid into Pennsylvania, during the Civil War. There were only a few soldiers in Pittsburgh, and the civilians were called on to aid in preparing its defenses. Rifle-pits were constructed to command the probable points of Morgan's entrance into the city. Trenches were dug on Squirrel Hill, Herron Hill, and at other points of vantage, and Mr. Kennedy was active in locating, superintending, and digging the rifle-pits around Herron Hill. Traces of these pits are still discernible there.

During Mr. Kennedy's connection with the Pennsylvania Railroad, he planned and had charge of the building of the old East Liberty stock yards, the first yard of its design to be built in the East.

In June, 1865, Mr. Kennedy resigned from the Pennsylvania Railroad to accept the position of Chief Engineer of the Oil Creek Railroad. This was a short road running from Corry, Pa., to Shafer Farm. It was built in 1865, by Messrs. Streeters and Struthers to meet the demands of traffic which had sprung up in that region during the petroleum excitement, and was a very profitable investment. At this time the road was owned jointly by the Pennsylvania Railroad, the New York Central Railway, and Streeters and Struthers, one-third of the stock being held by each of the interests.

Mr. David McCargo, at that time Assistant Superintendent of the Pennsylvania Railroad, was appointed General Superintendent of the Oil Creek Railroad by Mr. Thomas A. Scott, Manager of the Pennsylvania Railroad. On accepting the appointment, Mr. McCargo resigned from the Pennsylvania Railroad, and immediately tendered the position of Chief Engineer to his friend, Mr. Kennedy. As a result of conflicting interests, these arrangements proved only temporary, but, during the following year the whole project passed into the control of the Pennsylvania Railroad, of which it is still a part.

Mr. Kennedy became Chief Engineer and Superintendent of the Laurel Hill and Sand Point Railroad, with headquarters at Parkersburg, W. Va., where he remained until late in 1866.

In 1867, and until February, 1868, when the work was suspended for lack of appropriations, he served as Assistant Engineer under Sigismund Low, United States Assistant Engineer, on the survey and mapping of the Ohio River, between Portsmouth and Cincinnati, Ohio, being part of the general work of which the late W. Milnor Roberts, Past-President, Am. Soc. C. E., was the Engineer in Charge, as Superintending Engineer, Ohio River Improvements.

In 1868, under the Consolidation Act passed by the Pennsylvania Legislature, the Borough of Lawrenceville, together with the Townships of Peebles, Liberty, Collins, Oakland, and a portion of Pitt, were annexed and incorporated with Pittsburgh, then occupying a comparatively small area. With the annexation of these townships, the original area of the city was greatly augmented and enlarged, and in the enlargement was included the present East End, East Liberty, Homestead, and also the Villages of Frankstown, Hazlewood, Glenwood, and others.

In order to provide for a proper system of intercommunication, a department termed the City District was organized, the surveys for which were in charge of a District Engineer, to which position Mr. Kennedy was appointed in April, 1868. His principal work comprised a comprehensive system of city planning, locating the lines of main and auxiliary thoroughfares, to connect properly the streets of the old city with those of the outlying villages and other portions of the new sections of the city, the adjustment of the new streets for proper drainage and sewerage, as well as proper grades. This city planning entailed an enormous quantity of work, and was performed most conscientiously, all the engineering work being under his personal direction and supervision even to minute details, which in this case resulted in a perfect system of streets especially adapted to the varying topography with which the annexed district abounded.

About this time, the subject of a new water supply for the enlarged city was under advisement, and some surveys and studies had been made which finally culminated, on August 28th, 1871, in the appointment of a Board of Water Commissioners to supervise the construction of the new water-works system.

Mr. Kennedy then resigned his position as District Engineer in Charge of City Surveys of the new city district, and in the fall of 1871 was appointed Chief Engineer of the Pittsburgh New Water-Works.

The various sites for reservoirs which had been proposed, as well as others, were at once thoroughly investigated, one of the latter being at Verona, on the Allegheny Valley Railroad, about 8 miles north of Pittsburgh, on the south bank of the Allegheny River. The question of using the Allegheny River as a source of supply, or that of the Monongahela River, gave rise to much discussion, as each river had many adherents. In the case of the Monongahela, the water would be pumped into a reservoir in what is now Schenley Park. If the Allegheny was selected, the Hiland Avenue, Brilliant Hill, and Herron Hill reservoir sites would be used. Mr. Kennedy decided in favor of taking water from the Allegheny, and his decision of 45 years ago has been abundantly justified. During the winter of 1871-72, the reservoir sites of Hiland Avenue, Brilliant Hill, and Herron Hill were finally selected, and in the spring of 1872 detailed surveys were made and the work was prepared for contract. The Hiland Avenue Reservoir is the largest of the system and Herron Hill the smallest. Brilliant Hill was never fully completed, and is now known as Carnegie Lake in Highland Park, originally spelled Hiland, but later changed to Highland.*

In addition to the supervision and construction of the three reservoirs, Mr. Kennedy also had charge of the pipe distribution system, which included the large supply mains in Butler Street and Hiland Avenue, as well as the distribution system in other streets, prominently

* A description of the Hiland Avenue Reservoir will be found in *Transactions*, Am. Soc. C. E., Vol. LXXX, p. 690, being a discussion by Mr. Emile Low on Concrete-Lined Reservoirs, etc.

that in Second Avenue, as well as in many streets in East Liberty, generally known as the East End.

Two of Mr. Kennedy's assistants are yet living, namely Emile Low and James H. Harlow, both Members of the Society.

The reservoirs mentioned are models of substantial construction, and, although 40 years old, have required little or nothing for repairs.

Mr. Kennedy's connection with these operations was terminated in the early part of 1874, when the work was in an advanced state of completion.

In 1875 Mr. Kennedy went to Montana as Engineer of a hydraulic mining company. During that year he rode alone from Helena, Mont., to Walla Walla, Washington Territory, over the Mullan Trail, to visit his brother, then living in Walla Walla. Thence, he went to San Francisco, arriving there at about the time the Bank of California closed its doors, on August 27th, 1875.

During the three succeeding years he was engaged in private work in Pittsburgh, and in 1879 went to the Pacific Coast and was, until 1883, Principal Assistant Engineer of the Oregon Railway and Navigation Company, under Mr. Hans Thielson, Chief Engineer, whose son, Henry B. Thielson, was Assistant Chief Engineer, and who says of Mr. Kennedy:

"He was easily the most accomplished locating engineer he [Mr. Thielson] had ever been associated with. His most important works were the line from Pendleton across the Blue Mountains to the Grand Ronde Valley, located by him and built under his direction, and the first location between Portland and The Dalles on the Columbia River. Had it been possible to build the last-mentioned line as located by Mr. Kennedy, it would have reflected great credit on the locater as well as on the company. It was a bold location, admirably balancing conditions in the equation of curvature *vs.* cost. Unfortunately, the necessity of completing a connection between the Northern Pacific at Wallula and Portland, and the impossibility of obtaining the necessary labor to build the line as located by Mr. Kennedy within the time allowed by the management, made it necessary to break up the line temporarily. However, Mr. Kennedy had an opportunity later, while Chief Engineer of the Oregon Railway and Navigation Company, of revising the constructed line largely on the lines of his original location."

The line from Celilo to Wallula on the Columbia River was also located by Mr. Kennedy, and most of it was constructed under his supervision. He had actual charge of the construction of the lines built in Oregon at that period, and later, of the lines built in Washington and Idaho, including the several branches in the so-called Palouse Country, the extension of the main line to Spokane, and the important branch in the Cœur d'Alene Mountains.

From 1884 to 1886 he was Assistant Engineer of the Northern Pacific Railway, of which the late Gen. Adna Anderson, M. Am. Soc. C. E., was Chief Engineer and Virgil G. Bogue, M. Am. Soc. C. E., Principal Assistant Engineer, engaged along the Western slope of the Cascade Mountains, to and across Stampede Pass, and subsequently, during 1886 and part of 1887, in the Rocky Mountains of Central Montana, through the Prickley Pear Canyon and Boulder Valley.

On June 30th, 1887, Mr. Kennedy became Chief Engineer of the Oregon Railway and Navigation Company, and remained with the road until its absorption by the Union Pacific Railway in 1890.

In 1891 he was Chief Engineer of the location of the Columbia River and Astoria Railway.

Early in 1892, a number of prominent business men of San Francisco, Cal., took up the question of building a railway from San Francisco to Salt Lake City, as a line to compete with the Central Pacific and Southern Pacific. They organized a company and proceeded to discuss possible routes. Mr. Virgil G. Bogue, being at that time in San Francisco, suggested Mr. Kennedy as a fully qualified engineer for the undertaking. Mr. Kennedy, therefore, early in March, 1892, took up this work. As the outcome of his preliminary studies, he recommended investigations and surveys of several passes through the Sierra Nevada and Tehachapi Mountains. These reconnaissances were made by engineers selected by him and under his direction, but that of Beckwourth Pass he himself carried through. He also went over the proposed route from San Francisco *via* Stockton to Bakersfield, leading to passes of the Tehachapi Range.

Then followed preliminary surveys and estimates of the Beckwourth Pass Route, Mr. John T. Williams having charge between Oakland and Oroville, and J. Q. Jamieson, M. Am. Soc. C. E., of the part in the Sierra Nevada Mountains between Oroville and the State line. Mr. Bogue, subsequently, after thorough studies of many passes by himself and other engineers, recommended and adopted the general route indicated by Mr. Kennedy's studies between Sacramento and Beckwourth Pass as part of the Western Pacific, applying, however, a 1% maximum grade where the surveys already mentioned had been on 1.32 and 1.35% maxima.

The route suggested by Mr. Kennedy, from San Francisco *via* Stockton to Bakersfield, was subsequently utilized by the San Francisco and Great Salt Lake Railroad mentioned, except the part between San Francisco and Stockton, where another route was chosen in order to reach a terminus on the Bay at Point Richmond, instead of Oakland, which had been recommended by Mr. Kennedy.

In 1893 Mr. Kennedy was for a time engaged in Chicago on estimates of cost of a Belt Line from Waukegan to the Wisconsin State line.

Early in July, 1894, he was again appointed Chief Engineer of the Oregon Railway and Navigation Company, the property then being in charge of the Court, with Maj. E. McNeil as Receiver.

There had been a disastrous flood in the spring of that year, the Columbia River being higher than shown by any record, even traditionally, and great damage had been done to the roadbed of the railroad along the river. More than 100 miles of track, with the bridges, were destroyed, and through traffic was wholly stopped west of Umatilla, local passengers being transferred to boats and then again to rail to reach their destination. During this trying period, Mr. Kennedy worked almost continuously from July 4th to August 16th, sometimes without sleep for two or three days, and succeeded in repairing the damages caused by the flood in an incredibly short time, and at one-quarter the cost estimated by the former management.

In connection with the betterment work inaugurated soon after the late E. H. Harriman acquired control of this property, Mr. Kennedy made a study of every stream crossing, waterway, bridge, and culvert, also of every possible line change that would better the alignment or reduce the grade. The result of the surveys and estimates for these betterments were condensed into book form, and adopted by the Board of Directors in their entirety, and the work was carried out as proposed by him or his successors.

He was authorized to rebuild, in a permanent manner, hundreds of temporary structures, originally put in by him in the pioneer days, and also was privileged to eliminate curvature and reduce grades, which the heavier equipment and increased speed and traffic then demanded. This was all a labor of love for him. He delighted in working out the plans and details for these improvements, and fully appreciated the great economies of operation which would thereby result.

He remained with the company until 1905, when he was compelled to resign on account of a nervous breakdown. Mr. Harriman persuaded him to take a rest. His condition, however, did not improve to the extent of resumption of his responsibilities, and he tendered his resignation to Mr. B. A. Worthington, General Manager, on March 15th, 1905. This severance of relations was regretted by all his associates on the road.

In a letter to Mr. Harriman, written at the time he resigned, he said:

"I feel very grateful to you for your kind wishes expressed for my restoration to health which I believe is only a question of time, the trouble being more a nervous than an organic one. I have, however, already lost too much time, and, as the season advances, the work on the road will be pressing. I have, therefore, placed my resignation in the hands of General Manager Worthington."

After a long rest, with complete freedom from care, his health did improve. Late in 1905 he was associated with Mr. Bogue in New York, and became Consulting Engineer of the Western Maryland Railway. He was thus brought into active outdoor life again. This change materially helped to restore his health, so that when Mr. Bogue began the construction of the Western Pacific Railway, Mr. Kennedy was able to take up the duties of Consulting Engineer for a part of the time during 1907-08-09.

In the spring of 1915 his death was caused by an acute attack of pneumonia which lasted only 10 days.

In many ways Mr. Kennedy was marked by Nature for the career which he followed, and he united in his character exceptional traits making for the higher life. All who knew him, especially his subordinates, found him kindly and considerate. He had a quick perception of the good and true in others, and was generous in his judgments throughout a long life of varied associations and achievements. He never married, although he was domestic in his tastes, and a man to whom children particularly appealed. Beginning his professional duties at a time when public works were less numerous than now, he yet was constantly employed, gaining experience which his ready adaptability made of the greatest benefit when he assumed the larger responsibilities of later years. He may safely be called one of the great engineers of his time and country. Too much cannot be said, both of his ability to carry to successful completion any project seriously undertaken by him, and of his single-mindedness of purpose.

Like most men of his calling, Mr. Kennedy was above cheap advertising, relying on his record and reputation for continued success.

He will long be missed by both friends and associates. To his family his death cannot be other than an irreparable loss.

Mr. Kennedy was elected a Member of the American Society of Civil Engineers on September 6th, 1871, and was elected a Director on December 3d, 1901, to fill the vacancy on the Board caused by the death of George A. Quinlan, M. Am. Soc. C. E.

DAVID WILLIAMS, M. Am. Soc. C. E.*

Died November 27th, 1915.

David Williams, the son of Griffith and Sinal Williams, was born in Holyhead, North Wales, on February 6th, 1854. When still an infant he was taken by his mother to Richmond, Que., Canada, where his father was Engineer of Construction on what is now the Grand Trunk Railway. Mr. Williams attended the schools in Richmond and, later, St. Francis College, afterward serving as Lieutenant in the Light Artillery and being stationed in the Citadel at Quebec.

* Memoir prepared by R. Q. Hamilton, Asst. Engr., Boston and Maine Railroad, St. Johnsbury, Vt.

From 1874 till 1882, Mr. Williams was associated with Mr. H. C. Cleveland, a prominent Railway Locating Engineer of the Eastern Townships. In 1882, he joined the Engineering Staff of the Canadian Pacific Railway, being assigned to the Northwest Lake Superior Division, on which Division he remained until 1886. During his employment with the Canadian Pacific Railway, he had charge of the location of nearly 200 miles of track around the Great Lakes. In 1886, he was appointed Chief Engineer of the Drummond County Railway, now a part of the Intercolonial Railway System, and resigned from that position in 1887 to accept the office of Locating Engineer of the Hereford and Upper Coos Railroad, now a part of the Maine Central Railroad System. After completing his work as Locating Engineer, Mr. Williams had charge of the construction, and built nearly 100 miles of road into the extensive lumber regions in the Eastern Townships of Quebec.

In March, 1890, he was appointed Road Master of the Western Division of the Boston and Maine Railroad. In 1891, he was made Assistant to the Chief Engineer, which position he held until 1893, when he was appointed Division Engineer. He served as Division Engineer from 1893 until he retired from railroad engineering in 1911. During his connection with the Boston and Maine Railroad Mr. Williams had charge of the double-tracking of the Vermont Valley Railroad and the Sullivan County Railroad. After his resignation from the Boston and Maine Railroad, he had charge of the separation of grades on the Revere Beach and Lynn Railroad. In 1912, he was appointed Chief Engineer of the E. and T. Fairbanks and Company's plant, and had entire charge of the construction of the extensive additions to its home plant.

At the time of his death at St. Johnsbury, Vt., on November 27th, 1915, Mr. Williams was employed by the State of Vermont as Consulting Engineer to the Public Service Commission and the State Highway Commission.

Mr. Williams was a man of sterling qualities. His judgment was sound and practical, and given only after careful study and deliberation, and he was frequently called on as an expert engineer in litigation. To those who knew him best, he was a man whose friendship was most highly valued. Although by nature of a retiring disposition, when he was among those whom he loved, his reminiscences were a veritable well of knowledge.

On February 10th, 1891, he was married to Miss Lucina Mackay, of Cookshire, Que., Canada, who survives him.

Mr. Williams was elected a Member of the American Society of Civil Engineers on May 4th, 1898.

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